

ARCTIC ECOSYSTEMS IN PERIL: REPORT OF THE ARCTIC GOOSE HABITAT WORKING GROUP

Part II

HIGH GOOSE POPULATIONS:

CAUSES, IMPACTS AND IMPLICATIONS

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INTRODUCTION

Many species of Arctic breeding geese have increased significantly over the last thirty years (Ogilvie and St. Joseph 1976, CWS, USFWS and Atlantic Flyway Council 1981, Boyd and Pirot 1989, Owen and Black 1991, Fox *et al.* 1992, Abraham *et al.* 1996). In North America, these include lesser snow geese (*Anser caerulescens caerulescens*), greater snow geese (*A. c. atlantica*), Ross' Geese (*A. rossii*), greater white-fronted geese (*A. albifrons*), and some populations of Canada geese (*Branta canadensis*), e.g., *B.c. interior* of the Mississippi Valley Population and *B.c. parvipes* of the Short Grass Prairie Population. In addition, some temperate breeding Canada geese (*B.c. maxima*) have also increased (Rusch *et al.* 1995, Allan *et al.* 1995). Most increases are the direct or indirect result of human activities; their combined effects represent biomanipulation of goose populations on a massive scale. The mid-continent population of lesser snow geese, for example, now exceeds three million birds, and the population is increasing at a rate of at least 5% per annum (Abraham *et al.* 1996) ([Fig. 2.1](#)).

The intense foraging activities of lesser snow geese, greater snow geese, Ross' geese and some Canada goose populations, have altered plant communities in both natural and agricultural ecosystems (Lynch *et al.* 1947, Smith and Odum 1981, Giroux and Bédard 1987, Jefferies 1988a,b, Kerbes *et al.* 1990, Belanger and Bédard 1994, Didiuk *et al.* 1994, Ryder and Alisauskas 1995). Most species of geese feed in flocks on migration and wintering grounds. Many, including lesser snow geese, also feed in groups on the breeding grounds following hatch, hence it is not only the large numbers of birds, but also their colonial or gregarious behaviour and locally high densities that cause substantial changes to plant assemblages.

The chronic effects of disturbance by geese to different types of vegetation and soils are cumulative. Females display a high degree of philopatry to breeding grounds (Cooke *et al.* 1995) and in response to overall population growth, individual nesting colonies expand outward to occupy all suitable habitat and/or increase in density within suitable habitats (e.g. Ross' geese, Alisauskas and Boyd 1994, Kerbes 1994). The sustained use of a breeding site over a number of years allows little opportunity for recovery of the vegetation from the effects of foraging. The intensity of foraging, particularly in spring, varies from year-to-year and is dependent on the number of birds and on the prevailing weather conditions. In late springs, the prolonged cold and the presence of ice and snow delays the northward migration of birds, and at sites in the sub-Arctic and southern Arctic both local breeding populations and staging birds have considerable impact on vegetation (Jefferies *et al.* 1995). Most damage to vegetation, so far recorded, has occurred in habitats along the western and southern coasts of Hudson Bay and in James Bay. These localities, which are major staging and breeding areas for both lesser snow geese and

Canada geese, are undergoing isostatic uplift (ca. 1 cm/yr) and plant community development in these early successional environments is strongly dependent on coastal geomorphology. The destruction of vegetation which occurs at sites frequented by geese is the direct result of foraging and feedback processes that lead to further destruction of vegetation and desertification of landscapes (Srivastava and Jefferies 1996). The rate of loss of vegetation is rarely linear, once a threshold associated with the intensity of the feedback processes is passed, destruction is rapid (see later).

The effects of this cumulative damage on the geese and other fauna, on wetland and agricultural ecosystems, and on migratory bird management are significant and complex. Arctic coastal wetlands and their biological processes and components, in particular, are at risk from sustained high goose populations. The biology and well-being of individual geese have been affected (e.g., reduced body size, reduced gosling survival). Ducks, shorebirds and passerines suffer direct habitat loss, particularly nesting birds that are less mobile. Degraded soils alter the conditions for invertebrate and microfaunal growth. Aquatic systems in coastal areas are affected by eutrophication, increased water temperature, salinity, and increased evaporation, with probable consequences on the structure of invertebrate communities. In areas long-occupied by geese, faecal droppings have accumulated, and conditions may favour the spread of parasites and diseases, (e.g., renal coccidiosis, Gomis *et al.* 1996).

There are few precedents for dealing with problem (high) populations of migratory game birds. For harvestable wildlife in general, the wildlife conservation profession has focussed on ensuring stable or increasing populations consistent with wise use. For non-harvested wildlife it has emphasized protection or halting declines of rare species; it has dealt relatively little with population reduction or control of abundant native vertebrates

(Garrott *et al.* 1993) except where rare or endangered species recovery is limited (Goodrich and Buskirk 1995). The dilemma posed by high populations of geese present new challenges (Ankney 1996, Rusch *et al.* 1996) made more difficult because many of the negative impacts occur far away and unseen by the general public, whose understanding and support will be needed for action.

In this background report, we review status and trends of selected goose populations, the contributory causative factors, the biological impacts of high populations, the likelihood of recovery of affected systems, and some of the human interactions. In companion reports, the effects of various population manipulations is considered (Rockwell *et al.* 1997) and possible management actions are reviewed (Johnson 1997).

POPULATION STATUS AND TRENDS

In the following accounts, eastern Arctic refers to the area east of approximately longitude 95° W; the central Arctic refers to the area between 95° W and approximately 115° W, and the western Arctic refers to the area west of 115° W ([Fig. 2.2a](#), [2.2b](#)).

Lesser Snow Goose (LSGO)

LSGO populations in the mid-continent have been indexed annually during winter since mid-century. The mid-winter index (MWI) rose 300% from 0.8 million geese in 1969 to 2.7 million in

1994 (Mississippi and Central Flyway Councils, unpublished data) ([Fig. 2.1](#)). A complete photographic inventory of eastern Arctic nesting colonies by Kerbes (1975) suggested that winter indices averaged about half the actual spring number (e.g., when MWI was 0.8-1.0 million geese, he estimated 1.9 million at nesting colonies); Boyd *et al.* 1982) corroborated this underestimation and used a factor of 1.6 to adjust MWI. The probability of mid-winter index counts underestimating the real population size has probably increased as the population has grown, due to the daunting task of monitoring the expanding wintering area used by geese, and the limitations of survey techniques for large clustered populations. The current actual population of mid-continent LSGO geese is probably between 4.5 and 6 million.

Recent breeding ground surveys in the eastern and central Arctic have confirmed substantial growth at several colonies and establishment of new colonies ([Fig. 2.3a-d](#)) (Reed *et al.* 1987, Alisauskas and Boyd 1994, Kerbes 1994 and unpublished data, Cooke *et al.* 1995, Hudson Bay Project, unpublished data). D. Caswell, personal communication, conducted surveys on southwestern Baffin Island that revealed 1.2-1.4 million breeding adults in 1994 and 1995. LSGO

populations in central and western Arctic Canada apparently grew more gradually (than those of the eastern Arctic) before the 1980's but now (the last decade) appear to be on a similar track. Central and western Arctic nesting areas now each contain more than 500,000 breeding birds (*cf.* Alisauskas and Boyd 1994 in ROGO account below). The Egg River, Banks Island colony experienced extremely rapid growth from 1985 to 1995 (Dzubin 1979, Kerbes 1983, R. H. Kerbes, unpublished data). An Alaskan nesting population established in the late 1960s has grown gradually, partly through immigration (Johnson 1995).

Some exceptions.-- Unlike most LSGO populations, the total population returning in spring to Wrangel Island, Russia declined recently to 70,000 birds from 150,000 in 1970 (Pacific Flyway Management Plan, 1992) ([Fig. 2.4a](#)). Lesser snow geese that breed on Wrangel Island are composed of two different sub-populations that winter in separate locations, either in the Fraser-Skagit Delta system of British Columbia and Washington, or in California and Oregon (McKelvey *et al.* 1989, Syroechkovsky *et al.* 1994). An Asian population, thought to nest on the Arctic coast of the Russian Far East as far west as the Lena River and to winter in Japan, was eliminated due to human harvest (V.V. Baranyuk, pers. comm.).

The complex of nesting colonies on the West Hudson Bay coast, centered at McConnell River, grew exponentially from the 1940s to late 1970s to a high of 215,000 breeding pairs but has declined since 1985 to less than 75,000 breeding pairs (Kerbes 1982, MacInnes and Kerbes 1987, Kerbes *et al.* 1990, R. Kerbes, pers. comm.) ([Fig. 2.4b](#)). Habitat destruction by geese and emigration of adult geese to other nesting areas are implicated as causes of the decline.

Ross' Goose (ROGO)

ROGO are difficult to index because of mixing with LSGO in both winter and at nesting colonies. However, a technique using late winter surveys (when ROGO are somewhat isolated from LSGO) showed an increase in numbers from 8,000 in 1957 to over 38,000 in 1968 (Bellrose 1980). McLandress (1979) estimated a 7% per annum growth rate from 1964 to 1976, at which time the winter population index was 107,000 birds. Nesting birds in the Queen Maud Gulf region increased from about 2,000 in 1949 to 34,000 in 1965-67 to 188,000 in 1988 (Kerbes 1994) ([Fig. 2.5a](#)). Thus, almost 400,000 ROGO migrated from the breeding grounds in the early 1980s. Alisauskas and Boyd (1994) documented further growth of existing colonies and establishment of new ones. They suggested the nesting population at the 2 major colonies doubled between 1988 and 1990-91. They estimated a population of over 900,000 adult ROGO and LSGO combined in the Queen Maud Gulf area in 1990-91; ROGO make up about 42% (210,000) of the largest colony at Karrak Lake, which contained an estimated 500,000 total "white" geese in 1995 (R. Alisauskas, unpublished data).

A few nesting ROGO were present in most LSGO colonies in the eastern Arctic in the early 1970s (MacInnes and Cooch 1964, Prevett and MacInnes 1972, Prevett and Johnson 1977). Since that time, the population has exploded to an estimated 40,000 birds at the McConnell River colony, NWT in 1995 (R. Forsyth, Canadian Wildlife Service and R. Bromley, Government of Northwest Territories, unpublished data), and to 1,000 on western Baffin Island (D. Caswell, Canadian Wildlife Service, unpublished data). In addition, up to 14% of "white" geese within sections of the Boas River nesting area on Southampton Island, NWT are ROGO (T. Moser and K. Abraham, unpublished data). If most individuals from these eastern subpopulations migrate in fall to the mid-continent area, the overall number of ROGO there may exceed 100,000 birds. B. Sullivan (Texas Parks and Wildlife Department, unpublished report) provided an estimate in 1995 from Texas alone of 70,000 ROGO which supports this suggestion (see also Kerbes 1994).

Greater Snow Goose (GSGO)

The population with the best documented growth data among all white geese is the GSGO. A single population of this subspecies exists in eastern North America. It grew from a few thousand in the 1930s to 50,000 by the mid 1960s, to over 500,000 in fall migratory flights in the late 1980s (Gauvin and Reed 1987, Reed 1990). Spring migratory populations (measured by the use of complete photography on staging areas) reached 612,000 in 1995 (Reed 1996) ([Fig. 2.5b](#)). Following 7 decades of slow growth, the population increased seven-fold from 1965 to 1985 and it has nearly doubled between 1985 and 1995. Surveys of breeding numbers on the largest colony (Bylot Island) have been made every 5 years since 1983. They have showed an increase from 16,000 breeding adults in 1983, to 26,300 in 1988, to 55,000 in 1993 (Reed and Chagnon 1987, Reed *et al.* 1992, Reed, pers. comm.). In addition to the excellent long-term population monitoring, the geographic expansion of the breeding grounds, spring staging areas, wintering grounds, reproductive success and annual harvest have been recorded carefully (Reed 1976, Reed 1990, Gauthier *et al.* 1988, Bédard and Gauthier 1989). These data provide an excellent example of the information necessary to determine the causes of population increase of geese (Gauvin and Reed 1987, Reed 1992).

The rapid population growth phases of the mid-continent LSGO population, the ROGO and LSGO populations in Queen Maud Gulf, and the GSGO population all occurred at about the same time (Boyd, Cooch and Smith 1982, Kerbes 1994, Gauvin and Reed 1987). In the period between 1966/1967 and 1974/1975 all of these populations doubled. Since that time, LSGO have nearly doubled again, and GSGO and ROGO populations have achieved even higher growth rates.

Greater White-fronted Geese (GWFG)

Mid-continent Greater White-fronted Geese have, like other geese, increased dramatically over the past 40 years. In the Mississippi Flyway, only 12,000 were counted in the first coordinated aerial surveys of the mid-1950s (Yancey *et al.* 1958). They have increased over ten-fold to a 1996 MWI of 145,100 (K. Gamble, Mississippi Flyway Council, unpublished data); the increase has been similarly dramatic in the central flyway (D. Sharp, Central Flyway Council, unpublished data) ([Fig. 2.6a-b](#)). GWFG that winter in these flyways have been managed and monitored as two groups: Western and Eastern Mid-continent. However, Kraft and Funk (1991) cited evidence that this distinction might not be valid and recognized an urgent need for better information to delineate and monitor populations. Since then, coordinated September surveys in Saskatchewan and Alberta and the northern states of the Central and Mississippi Flyways have been conducted (from 1992 to 1995). These surveys tallied 625,847 geese in 1992, 677,489 in 1993, 727,726 in 1994 and over 1 million in 1995 (Canadian Wildlife Service, D. Neiman, unpublished data, Zenner 1996).

Krapu *et al.* (1995) studied the spring staging ecology of mid-continent GWFG, particularly the use of habitat, nutrient accumulation, and agricultural food contributions to energetics of pre-breeding birds. They believe that GWFG now "arrive on Arctic breeding grounds with larger and less variable fat reserves than before modern agricultural development". They attribute this to increased corn availability and use, beginning in the 1940s when corn harvesting techniques provided waste grain, but accelerating in the 1960s and 1970s when corn yields increased. They suggest that increased fat deposition in spring positively affects recruitment.

GWFG in portions of the Central Flyway where wetland loss is >90% (Krapu *et al.* 1995, Friend and Cross 1995) are vulnerable to disease epizootics, especially avian cholera. High concentrations on the relatively few remaining roosting wetlands allow for easy transfer of the disease. Population growth as exhibited in recent years likely exacerbates these problems.

Giant Canada Geese (Giant CAGO)

Populations of Giant Canada geese have grown from near extinction to nuisance levels over the past 40 years; from an estimated 55,000 birds in 1965, the various populations of temperate breeding birds now contain an estimated 2 million geese, with over 1 million in the Mississippi Flyway alone (Rusch *et al.* 1995, Rusch *et al.* 1996) ([Fig. 2.7a](#)). Much of this growth is directly attributable to planned management actions of agencies and private sponsors, including restoration and introduction programs, closed hunting seasons, and restricted harvest expressly intended to increase populations. Equally, however, this growth is an outcome of the species adaptability and colonization of unoccupied habitats under protection. This has occurred in an urban and rural landscape

much altered since they were extirpated from many jurisdictions, which offered countless unintentional sanctuaries. The agricultural energy subsidy evident in the growth of white goose populations is similar in effect for Canada geese and is in part responsible for the growth of these goose populations. ([Fig. 2.7b](#)).

Mississippi Valley Population Canada Geese (MVP CAGO)

The Mississippi Valley Population of Canada geese is the largest population of the *interior* subspecies. Management through harvest regulations and habitat programs have had the objective of increasing its size to 300,000 in winter (USFWS 1979) and later to 900,000 in spring (Tacha 1991). Sustained increases have occurred over the past 40 years, from less than 40,000 birds in winter to a current MWI of over 900,000 (Rusch *et al.* 1995, Mississippi Flyway Council, unpublished data) ([Fig. 2.8](#)). A period of rapid growth from 1964 to 1975 was followed by an erratic pattern until 1983, during which time the annual count reached an unprecedented peak of 576,000, but the mean MWI did not change significantly. The counts were possibly confounded by undetected growth of giant populations at that time. Since 1983, the population has rapidly and steadily increased, resulting in a tripling of the MWI. However, debate about the accuracy of the MWI and the inclusion of giants led to initiation of comprehensive breeding ground surveys in 1989. These show a spring population of 700,000 to over 900,000 from 1989-1996 and a fall flight of 1 to 1.5 million varying annually depending on current and recent years' production (J. Leafloor, unpublished data).

One of the consequences of the sustained growth in numbers is the change in nesting density and occupation of new range. Before about 1975, few nesting or brood-rearing Canada geese occupied the near coast (10 km) zone of Hudson Bay or northwest James Bay (H. Lumsden, pers. comm.). Annual photographic surveys from 1958-1970 made during the brood-rearing period covered the coast from Moosonee, Ontario to Eskimo Point, Northwest Territories (Hanson *et al.* 1972). A special effort to photograph broods for early assessment of reproductive success became possible only in the early 1980s. In addition, banding of coastal breeders was difficult and limited until the early 1980s. This suggests, at the least, an increase in use of coastal brood rearing areas, possibly a result of increased population density. Numbers of breeding pairs have tended to decline over the 1991-1996 period (J. Leafloor, pers. comm.), which may be an early signal of the population nearing its carrying capacity. A complicating factor is the increase of nesting lesser snow geese in the coastal zone of the MVP range from 1970 to the present; two small colonies (<2500 pairs) have been established and the major colony at Cape Henrietta Maria has nearly quadrupled in number, and doubled in area of coastal range occupied (Hudson Bay Project, unpublished data).

HOW LARGE WERE WHITE GOOSE POPULATIONS BEFORE THIS CENTURY?

Before this century, accounts of abundance are narrative and anecdotal. None of the estimates was documented or quantified for comparison with modern methods. All of them precede the era of aerial surveys and none involved a coordinated, simultaneous air or ground survey. We summarize these below, but urge caution in interpretation because methods of numerical estimation are usually anecdotal and not statistically reliable.

LSGO

Bent (1962) writes of the "astonishing abundance" of lesser snow geese and blue geese (then described as two species) in the first decades of this century, particularly on the Gulf Coast and in Manitoba (i.e., what we now call the mid-continent population). The number of mid-continent LSGO in the 1930s was judged to be up to "3.5 million on the Gulf Coast in winter" (McIlhenny, in Gresham 1939), and "4-5 million in Manitoba in spring" (Soper, in Johnsgard 1974). McIlhenny (1932) estimated 1.25-1.5 million geese in a single flock. Johnsgard (1974) commented that these early estimates were "either wildly optimistic" or "mid-continent snow geese have declined greatly in recent decades". Yet Bent (1962) does not mention declines, nor does McIlhenny (1932) during his 50 years of close association with blue geese on the Gulf Coast.

Evidence of LSGO nesting colonies of sufficient size to corroborate these large migration and winter estimates of LSGO is lacking. Nesting areas were first visited by non-natives in 1928-30 (Soper 1930, Sutton 1931). Manning (1942) suggested hesitantly that there were 100,000 (presumably nesting) birds of each color on southwestern Baffin Island and 30,000 on Southampton Island (calculated from his counts and color ratios), but Kerbes (1975) termed Manning's estimates "minimum" because of the technique used (a coastal boat survey). Although these records suggest a fall flight of about 0.5 million birds in the late 1930s (similar to the first coordinated winter surveys in the Mississippi Flyway which estimated 440,000 (average of 1954-56) (Yancey *et al.* 1958), they are far short of 3.5-5 million! If there were that many birds during the first third of the century, what happened to them between then and the first coordinated winter surveys in the mid-1950s? We know of no evidence of massive disease outbreaks or die-offs, nor is there any hint of a massive hunting harvest (this was relatively early in the Migratory Bird Convention era and enforcement was strict).

ROGO

According to Bent (1962), ROGO were "the rarest of the geese which regularly visit the United States" by the 1920s. However, he mentions some evidence of their abundance prior to 1886, such as several thousand present each spring on the Missouri River (Montana). In California in winter, ROGO were "often quite common" and because of tameness "many are shot for the market". Ryder and Alisauskas (1995) cite Grinnell *et al.* (1918) as support for the suggestion that open market hunting may have contributed to the rarity of Ross' Geese at the beginning of the century.

GSGO

Concerning numbers of GSGO, early explorers wrote about "many thousands of white and grey geese" near present Québec City in 1535 (Jacques Cartier) and "many wild white geese" in the same area in 1663-64 (Fr. Paul Lejeune and Lalement) (Anonymous 1981, 1992). However, they "could not be called common" on the Atlantic coast by the late 1800s according to Bent (1962). The GSGO population was only 3,000-4,000 from the 1880s until the 1930s, and although it was suggested they were formerly more common, we found no specific statement of reasons for a possible decline (e.g., no evidence of decrease due to market hunting). A. Reed (pers. comm.) studied the ancient literature and gained the impression that GSGO were never abundant in the 1500s through 1900. Although hunting on the small population may have helped check population growth, he too found no evidence of excessive exploitation. He posed the question of whether a more severe climate in the Arctic during that period (the so-called Little Ice Age) may have kept numbers low because of frequent breeding failures.

Summary

What can we conclude about current versus former populations sizes? In the case of LSGO, abundance itself may have masked any trends; the difference between 0.5-1 million and 4-5 million would have been difficult to detect before consistent survey methods, as it is even now. Indeed, despite their abundance, contact with humans was infrequent because of the remoteness of breeding areas, and the limited number of staging areas along migration routes. In the case of ROGO and GSGO, migration concentrations and wintering sites overlapped with areas of early settlement which subsequently developed as human population centres in North America. Although their suggested former abundance apparently did not equal current population levels, a real decline appears to have occurred before this century and but only ROGO may have resulted from human activities.

EXPECTED WHITE GOOSE POPULATION EVENTS

If current agricultural and goose management practices are maintained, we expect continued growth of all populations for the foreseeable future, except the Wrangel Island LSGO. The western Arctic and western Central Flyway LSGO populations will escape from control by hunting (i.e., adult survival will increase). Western Arctic spring staging areas and nesting areas, which are predominantly fresh-water environments, should then experience increasing degradation similar to that already documented in these habitats in the Hudson Bay and central Canadian Arctic resulting in a decrease in survival of flightless young and other condition-related effects. More nesting colonies are likely to be established where suitable habitat exists. However, Alisauskas and Boyd (1994) speculate that prime nesting sites of Central Arctic Ross' and Snow Geese (shallow lakes with islands preferred as colony sites) are now in short supply and these geese must exploit other habitats. They appear to be spreading westward and northward into favoured range of small Canada Geese and White-fronted Geese. In southern Hudson Bay, most areas of extensive salt marsh capable of sustaining large colonies are now occupied (K. Abraham, R. Jefferies and A. Jano, unpublished data). Use of other habitats, particularly *Carex aquatilis* fens, is expected to increase.

Populations of all three white geese may experience an increase in the frequency of disease outbreaks in wintering and migration areas, but the mid-continent LSGO population, at least, appears to have the capacity to absorb many such small events without the overall population growth being slowed. Disease mortality effects on populations of other birds sharing these areas may be more detrimental.

FACTORS CONTRIBUTING TO HIGH POPULATIONS OF WHITE GEESE

Several factors coinciding in time and location have contributed to the observed population growth rates of white geese.

Agricultural food resource subsidy in winter and migration

Snow goose population size was once thought to be limited by over-winter survival, due to the species' apparent narrow definition of suitable winter habitat (salt marsh) and destructive foraging (grubbing) of vegetation resulting in

depletion of food resources (Lynch 1975). Wintering habitats along the Gulf of Mexico (LSGO) and Atlantic coast (GSGO) were primarily restricted to coastal bulrush (*Scirpus* spp.) and cordgrass (*Spartina* spp.) salt marshes (McIlhenny 1932, Bellrose 1980, Anonymous 1981, Smith and Odum 1981). The area of habitat available for wintering LSGO on the coasts of Texas and Louisiana was somewhat more than 200,000 ha. After the 1940s, LSGO expanded their foraging range (Lynch 1975) by incorporating rice prairies immediately adjacent to coastal marshes. Overall, there was nearly 400,000 ha of land in rice production at that time. Although coastal marsh habitat loss or change has been implicated (e.g., oil and gas development, urban expansion, dredging and filling; Bent 1962, Robertson and Slack 1995). Lynch (1975) argued that these anthropogenic effects were a minor factor in the changing pattern of land use by the birds, particularly because refuges were established in coastal marshes to protect such habitats. Louisiana and Texas had 223,000 ha (550,000 acres) of protected marshes in the early 1970s (Lynch 1975). The reliance of LSGO on rice prairies has increased further since the mid 1960s (Bateman *et al.* 1988, Hobaugh *et al.* 1989, Widner and Yaich 1990). Agricultural and hunting management practices that provided large areas of shallow water suitable for night roosting played an important role in expanding this use to interior rice prairies. The increase in the area of rice cultivation and the use of nitrogenous fertilizers have been dramatic since that time, and LSGO and ROGO now forage in over 900,000 ha of rice fields in Texas, Louisiana, and Arkansas. Although the harvested rice area has declined in the last decade, the yield per hectare on the upper Texas coast has continued to increase due to second cropping and more efficient harvesting (Hobaugh, Stutzenbaker and Flickinger 1989, Robertson and Slack 1995).

Further north in the mid-continent region and in the mid-Atlantic coast, geese exploit other cereal grains (Alisauskas *et al.* 1988, Anonymous 1981, Hill 1992, Reed 1992). A major impact of this conversion of natural grassland and bottom land forest habitats to agricultural use is that the former depletion of winter food resources in salt marshes, which presumably resulting in mortality or sublethal effects on body condition, has been removed as a factor limiting survival and population growth.

Corn, wheat, barley, oats and rye cultivation in the mid-western and northern prairies provide additional nutrient and energy subsidies for LSGO. Snow goose preference for corn in Manitoba in spring minimizes the historical influence that drought in natural habitats may have had on condition of pre-breeding geese (Alisauskas and Ankney 1992, Davies and Cooke 1983). Due to the important role of stored reserves in determining breeding success (Ankney and MacInnes 1978), this more reliable food source would lead to higher average reproductive potential. In fall, availability of waste grain in harvested fields has delayed the southward fall movement of geese and blurred the definition of "winter" range (Alisauskas *et al.* 1988). This effect is additive to the effects of refuges (see below).

On the Atlantic coast, GSGO formerly wintered in a restricted area of coastal salt marsh. Compared with LSGO, their use of habitats other than coastal marshes is more recent and more limited (Anonymous 1981, Reed 1992), but GSGO have fed in winter in agricultural cropland since about 1970 (Hill 1992). Historically, spring staging was limited to the tidal brackish *Scirpus* spp. marshes of the St. Lawrence River. In the late 1960s GSGO began to forage in agricultural land in Québec during spring (Reed 1992) as a result of a growing population and the cumulative annual depletion of *Scirpus* spp. plants (Gauthier *et al.* 1988).

Refuges placed in close proximity to traditional feeding areas and the loss of salt marsh as a consequence of development (Hindman and Ferrigno 1990) apparently assisted this shift. Ironically, concentrations of GSGO feeding intensively on refuge impoundments may have pushed marsh plants beyond their threshold of regeneration. Geese may have been forced to seek off-refuge foods in agricultural lands. In addition, industrial and urban development limited available salt marsh food supplies, and where forage was available, hunting pressure was high. In effect, a positive feedback was established between broadened habitat use and the population increase of LSGO and GSGO on both wintering grounds and staging areas.

The effect of refugia on migration routes

National Wildlife Refuges, state refuges and other wildlife areas were established throughout the United States, especially from the mid 1930s to the 1970s to protect and restore wetland habitat for breeding and migrating waterfowl and other wetland-dependent birds (Bellrose 1980). The attractiveness of these protected environments to waterfowl was quickly evident. The subsequent interruption of migration of LSGO and northward shift in the fall was particularly rapid and dramatic in the central United States from North Dakota to Louisiana and Texas. This eventually led to a reduction in traditional long distance flights from northern staging areas to Texas (Johnsgard 1974), and from James Bay to Louisiana (Cooch 1955).

Hunters were also attracted to some refuges which provided hunting opportunities, and in these places mortality increased (Johnsgard 1974). High local harvest rates near some refuges, as a result of both anticipated and unforeseen events (e.g., firing lines at refuge boundaries) may have led to poorer survival of birds using refuges than those that fed and roosted elsewhere. However, during the 1970s, changes in hunting practices near refuges included a reduction of firing lines, creation of no-hunting zones, manipulation of croplands to provide food, and a restricted harvest of geese on refuges and off refuges. The management practice of half-day hunting (Schroeder 1963) was initiated to hold migrant geese longer to increase hunting opportunities and local harvest, but its success also appears to have influenced distribution. These factors led to such migration sites functioning as true refugia (Frederick and Klaas 1982). Long-term reduction in the hunter harvest is consistent with the hypothesis of

disproportional growth of population units using refuges (Raveling 1978). These refuges may thus function as loci for population growth and exploitation of surrounding "new" agricultural foods. Note that these events took place in the mid 1970s, the same time as the other factors contributing to the overall population increase of white geese appear to have taken effect.

Lower harvest rates

Annual survival of LSGO adults from Hudson Bay increased from about 78% in 1970 to about 88% in 1987 (Francis *et al.* 1992). The principal cause of mortality of adult geese in recent decades is hunting (Owen 1980). The expansion of the winter range of mid-continent snow geese and the lengthening of fall migration stopovers at northern latitudes has had a significant effect on dispersion of geese, hunter access and exposure to hunting. Harvest in the central US has declined along with hunter numbers over the past 25 years (Fig. 2.9a). More importantly, harvest rates (measured as proportion of mid-winter indexed population) declined from near 40% to under 8% annually (Fig. 2.9b) (see Rockwell *et al.* 1997). Increases in harvest per hunter (Fig. 2.9c) have not compensated. Canadian harvests of lesser snow geese have also declined in recent decades (Fig. 2.9d). The increase in survival may have been due, therefore, to a reduced overall harvest rate. If so, the beginning of LSGO population "escape" from constraining effects of annual harvest occurred in the early 1970s.

GSGO harvest rates from the 1880s to the 1930s are not recorded but presumed to be high. Hunting of this subspecies was prohibited in the United States from 1931 to 1975 (Gauvin and Reed 1987) in order to increase survival and population growth. The population grew at a slow rate from 1910 to 1960. Significant growth did not occur until 1950 which suggested that hunting mortality alone was not responsible for low population growth. There is no evidence that habitat was in short supply (Reed, pers. comm.). Perhaps periodic weather related failures were in part, responsible for checking growth. Additionally, traditional use of coastal marshes (i.e., behaviour), lack of development pressure, and the low population numbers (i.e., little density dependent foraging competition) may have kept them from finding agricultural foods.

From 1967 to 1988, three distinct periods were recognized: the first (1967-1974) was characterized by legal seasons in Canada only, by variable but generally low harvest (mean 12,800 geese/yr) and a mean kill rate of about 10%; during the second (1975-1981) hunting occurred in both countries and mean harvest (51,600/yr) and mean kill rate (23.9%) increased; in the third (1982-1988) the mean harvest rose to 59,000 but the kill rate decreased to 18.5%. A more recent analysis covering 1989-1993 (Reed, pers. comm.) showed a continued increase in harvest (mean 74,500 geese/yr) and a further decrease in kill rate (mean 13.5%). The addition of a U.S. hunting season in 1975 resulted in larger harvests and, initially, in increased harvest rates but this was insufficient to stop steady

population growth. Since the early 1980s, harvest rates have been decreasing, and the spring population has increased by an average of 10% annually (1980-1996) (Reed, pers. comm.). This inability of hunting to control numbers of GSGO occurred about the same time it ceased to control population size of mid-continent LSGO.

Climate amelioration in the Arctic

A general warming trend from 1961-1990 has occurred in the central and western Canadian Arctic regions (Cohen *et al.* 1994) which include major breeding areas of LSGO and ROGO. MacInnes *et al.* (1990) showed that LSGO nesting occurred progressively earlier in the Hudson Bay region from 1951 to 1986. They suggested it was, in part, due to climate amelioration. As reproductive success in Arctic geese is positively correlated with early spring melts (reviewed by Owen 1980), warming of nesting areas could have led to higher annual population growth rates of mid-continent LSGO. Long term trends in decadal climatic patterns have shown the decade from 1970 to 1980 to be an anomalous warm period in the southern Hudson Bay region (W. Skinner, unpublished data) during which time spring melt occurred almost 15 days earlier than in the previous and succeeding decades. Thus, rather than a steady climatic improvement, there may have been a brief window of more favourable conditions that reduced the frequency of reproductive failures (the "boom-bust" pattern) typical of Arctic goose productivity up to 1980 (Owen 1980). Boyd *et al.* (1982) were not able to relate the upward trend in numbers to weather patterns between 1964-79, but qualified this finding because of the measures of breeding success that they used. However, with the exception of poor or bust production in 1972 (LSGO, GSGO), 1974 and 1976 (GSGO) and 1978 (LSGO) they had periods of sustained good reproductive success, as measured by proportion of goslings to adults in fall flights and on the wintering grounds (Boyd *et al.* 1982, Gauvin and Reed 1987). Years of poor reproduction do not always coincide between low and high arctic areas. GSGO showed decreasing frequency of "bust" years (<10% juveniles in fall) up to 1988 (Reed 1990); three times in the decade 1956-65, twice in 1966-1975 and once in 1976-1988. But in the last eight years (1989-1995) there have been two bust years (Reed, pers. comm.). The striking feature of this long term data set is the eleven year stretch from 1975 through 1985 in which there were no bust years and in which juveniles in fall averaged 27%.

The southern shift of nesting range of LSGO

The distribution of breeding birds has changed dramatically since the late 1920s. As a result, the centre of LSGO breeding range in the eastern Canadian Arctic geese has moved south to areas with a less severe climate (i.e., rather than climate change *in situ*). Snow clearance, on average, is 2 weeks earlier at Cape Henrietta Maria than at Baffin Island (Kerbes 1975). Before 1940, all known nesting colonies of lesser snow geese in the eastern Arctic were north of 60°N

(Cooch 1958, 1961), whereas by 1973, 40% of the entire population was nesting south of that latitude as far as 55°N (Kerbes 1975).

MacInnes *et al.* (1990) suggested that with an earlier average start to nesting and a longer growing season, higher average annual production would result in population growth of these southern colonies. Evidence from Cape Henrietta Maria (Hudson Bay Project, unpublished data) and La Pérouse Bay (Cooke *et al.* 1995)(Fig. 2.3) supports this assertion. However, the slow growth of each colony in the first 2 decades following establishment argues against this as the sole mechanism to account for growth. Northern colonies continue to experience occasional weather-related "busts" in production (e.g., 1972, 1978; Boyd *et al.* 1982, and 1983, 1992; Kerbes, pers. comm.). Some birds which would normally nest in northern colonies may be induced in some years to nest at southern latitudes by these late melt conditions (Hanson *et al.* 1972, Geramita and Cooke 1982, Hudson Bay Project, unpublished data).

LSGO populations have also expanded their breeding range in the central Arctic, both on islands and interior mainland (McCormick and Poston 1988, McCormick 1989, Alisauskas and Boyd 1994, Kerbes 1994, B. Bromley, pers. comm.) where the long-term climate trend has been a gradual warming (Cohen *et al.* 1994).

SUMMARY OF CAUSATIVE FACTORS

A nutrient and energy subsidy derived from foraging in agricultural croplands in several seasons and an expanded migration and winter range have been the major influences enabling geese to increase in numbers in recent decades. Climate warming on breeding areas and expanded breeding range are likely secondary causes. Reduced harvest rate appears to be an effect rather than a cause, even if harvest rate was limiting population size before the 1970s. While there are population density-dependent effects, such as decreases in body size in LSGO (Cooch *et al.* 1991, Cooch *et al.* 1991) and GSGO (Reed and Plante 1997) and poorer body condition/higher gosling mortality in LSGO (Cooch *et al.* 1993, Williams *et al.* 1993), these adverse effects are more than offset, at the population level, by increased adult survival (Francis *et al.* 1992) and by "cheating" (see below).

Once the nutrient-energy subsidy was established on migration and wintering grounds, the overall landscape use by geese became inherently unstable. The geese are recipients of an increasing nutrient and energy subsidy and as such they represent an output of the agro-ecosystem at the landscape level. Expected density-dependent effects such as declining natality and increasing mortality fail to operate because of this subsidy.

Geese also "cheat" density-dependent regulation by their dispersal behavior on the breeding grounds both within seasons and between years. Increased nesting at the edges of existing colonies leads to colony expansion (MacInnes and Kerbes 1987, Reed and Chagnon 1987, Alisauskas and Boyd 1994, Kerbes 1994, Cooke *et al.* 1995). Dispersal of family groups after hatch to areas distant from nesting sites ensures that the birds do not forage in the most severely degraded areas (Cooch *et al.* 1991, Hudson Bay Project, unpublished data, R. Alisauskas and S. Slattery, unpublished data). In addition, new nesting colonies establish away from traditional sites that have been degraded (Alisauskas and Boyd 1994, Kerbes 1994). The apparent decline of the McConnell River and west Hudson Bay nesting complex can be interpreted in this context. It may be an example of how local carrying capacity was exceeded as the population grew and occupied new areas, but that at some point further dispersal took the form of emigration to a distant habitat (e.g., to the Rasmussen Basin lowlands, McLaren and McLaren 1982 and perhaps to Queen Maud Gulf, *cf.* Kerbes 1994). It may appear that, if the birds can disperse, the problems of habitat destruction are less urgent. However, as we discuss below, under the continued pressure of expanding populations of geese, the rate of destruction is accelerating, the total area affected is large and significant, and the habitats remaining undamaged are non-preferred and even marginal and ultimately, finite.

The Wrangel Island LSGO population decline is real and appears to be related to density- independent factors, including weather conditions on the breeding grounds and the length of their migration route. A series of late summers in the early 1970s virtually eliminated recruitment of new breeders. A long-term cooling trend is also evident for the high latitudes of the Russian Far East (Cohen *et al.* 1994), unlike most other LSGO breeding areas. Harvest rates have also been higher for Wrangel Island birds than others until very recently (S. Boyd, pers. comm.). Historically, harvest on the breeding grounds was also very high.

Currently, both winter subpopulations have access to extensive agricultural lands (i.e., they should both benefit from the agricultural subsidy effect). Spring migration routes differ, however, with the California-Oregon group following an interior route coincident with western Arctic LSGO and central Arctic ROGO through the grain producing areas of Saskatchewan, Alberta and western Montana. At least part of the Washington-British Columbia wintering group migrates in steps from one natural river estuary/coastal marsh to another (e.g., Stikine River) where they feed principally on *Carex lyngbyei* (S. Boyd, pers. comm.). Thus, they differ in spring diets and may not benefit from the spring energy subsidy.

IMPACTS OF HIGH POPULATIONS ON ARCTIC AND SUBARCTIC HABITATS

Foraging Methods

The different foraging activities of the geese are described based on observations made mostly in coastal areas of Hudson and James Bays or reported in the literature. Understanding these differences is essential to a clear perception of impacts at different times of the year and in different habitats that geese have on vegetation and soil processes.

Grubbing of below-ground biomass

This refers to the digging and uprooting of roots and rhizomes of plants, in general, and graminoids (grasses and sedges), in particular ([Fig. 2.10](#)). The grubbing which takes place mainly in spring (but not exclusively) is dependent on the upper layers of sediment thawing for at least some hours each day. It is restricted to snow-free sites where the layer of vegetation and plant litter is thin and where seasonal above-ground growth of vegetation has not started. Where these conditions occur the birds are able to break open the turf and forage on below-ground biomass. Greater and lesser snow geese and Canada geese grub extensively immediately after snow melt. Some further grubbing may occur at the end of the season in late July and August, when above-ground tissues are senescing and reserves are being transported to below-ground organs. We have observed only lesser snow geese foraging in this manner in late summer, but in degraded environments with a shortage of food resources it may be practised by other species as well. Grubbing is a major foraging technique of LSGO on migration routes and in winter in the Gulf of Mexico coastal marshes, and of GSGO on the Gulf of St. Lawrence tidal marshes, and in east coast tidal marshes of the United States.

Shoot pulling of sedges

This type of foraging occurs in spring and is restricted to fresh-water mires (wetlands with an organic substratum). Lesser snow geese pull individual shoots of large sedges (>20 cm in height from a tussock)([Fig. 2.11](#)). They eat the white basal portion of the shoots which is rich in soluble nitrogen compounds and carbohydrates and discard the remainder (Gadallah and Jefferies 1995a). Removal of shoots by geese can occur in oligotrophic, mesotrophic and eutrophic sedge communities. *Carex aquatilis*, *Eriophorum angustifolium* and *Carex X flavicans* are examples of preferred forage species. The only grass species in wetlands from which shoots are pulled frequently are *Dupontia fisheri* and *Arctophila fulva*. However, in sandy or gravel areas the geese pull up shoots of lyme grass (*Elymus arenarius*).

Grazing

A large number of species are grazed on different occasions during the snow-free season ([Fig. 2.12](#)). The selectivity of different species appears to be linked to plant phenology and nutritional quality (Jefferies *et al.* 1994, Gadallah and Jefferies 1995a). Some coastal salt-marsh graminoids show enhanced compensatory shoot growth following defoliation and are subject to multiple defoliations throughout the season (e.g. *Puccinellia phryganodes*) (Cargill and Jefferies 1984, Hik and Jefferies 1990, Hik *et al.* 1991). In contrast, other species either show only limited compensatory growth or no growth following defoliation (Zellmer *et al.* 1993). Under conditions of intense grazing, the pseudostem of grasses such as *Puccinellia phryganodes* may be damaged and the regrowth of swards severely impaired. Ross' geese may be able to graze swards of *P. phryganodes* lower than lesser snow geese, because of the shape of their bills. In damaged, heavily grazed swards the former species may be capable of obtaining some forage, unlike lesser snow geese.

In addition to the salt-marsh graminoids described above, the following species are grazed at different times of the season in the Hudson Bay region: *Senecio congestus*, catkins of *Salix* species (early spring); *Potentilla egedii*, *Plantago maritima*, *Stellaria humifusa*, *Triglochin palustris*, *Triglochin maritima*, *Carex aquatilis*, *Eriophorum angustifolium* (all of these species in early to mid-summer); *Festuca rubra* and *Calamagrostis deschampsoides* (mid-summer). In fall birds eat *Potamogeton filiformis*, the seed heads of *Triglochin* species, as well as the shoots of *Equisetum* and a range of *Carex* species (Prevett *et al.* 1979).

Berry-feeding occurs on ericaceous tundra during migration (Reed, pers. comm.). Baffin Island LSGO and Atlantic Canada geese appear to feed heavily on the berry crop on the Ungava Peninsula in both spring and fall. Similarly, LSGO feed on berries on tundra ridges along the Hudson Bay coast (K. Abraham, pers. obs.).

Prime Forage Species

Plant species selected by greater and lesser snow geese as prime sources of forage differ depending on the geographical location of the breeding colony (see below). The prime forage species from Wrangel Island and Bylot Island grow at sites where there is a well developed peaty substratum that may have a high water content and which is mesotrophic or oligotrophic. In contrast, the forage species from the Hudson Bay lowlands grow either on mineral soils or where there is only a thin veneer of organic material. Because of the different tolerances of species to foraging, and the different intensities of foraging, the effects of the geese on plant communities at the various geographical locations are not necessarily similar. Most breeding colonies of snow geese are coastal in distribution in the Arctic and sub-Arctic, and much of the damage to vegetation described below is based on changes that have occurred to vegetation in the coastal zone of the Hudson Bay lowlands. The mid-continent population of lesser snow geese breeds in this region.

Experimental field evidence from feeding trials at La Pérouse Bay with captive goslings, as well as evidence of the correlation between amounts of standing crop and gosling weight, indicate that in early life the salt-marsh graminoids meet the nutritional requirements of goslings more successfully than other types of forage (Gadallah and Jefferies 1995b; Cooch *et al.* 1993). Elsewhere in the Arctic, other species such as *Dupontia fisheri* and *Eriophorum* species are a source of high quality forage (Gauthier *et al.* 1995) and meet the nutritional demands of goslings. These species grow on an organic substratum rather than in mineral sediments.

Isostatic Uplift and Development of Salt-Marsh Plant Communities in the Hudson Bay and James Bay Region

The Hudson Bay region is undergoing isostatic uplift at approximately 1 cm/yr. The actual rate has been estimated to be between 0.5 and 1.2 m per century, depending on the proximity of sites to epicentres of uplift (Andrews 1973). The present-day coastal zones have emerged within the last 1000 years. The rate of uptake and associated modifications of the soil environment influence plant successional processes. Although grazing by geese of salt-marsh vegetation retards the development of dicotyledonous plants (the apical meristem is destroyed by grazing, whereas in graminoids the meristem is basal and clipped leaves continue to grow, (e.g., a lawn) and maintains the *Puccinellia phryganodes* - *Carex subspathacea* grazing lawn, so that the successional “clock” is being reset each year, eventually the effects of isostatic uplift modify the physical environment and result in the replacement of *Puccinellia* and *Carex* by *Calamagrostis deschampsioides*, *Festuca rubra* (grasses) and dicotyledonous plants. The interaction between the grazer and the vegetation maintains the *Puccinellia* - *Carex* community, as long as it can overcome the environmental constraints imposed by isostatic uplift.

Although this type of vegetation is well developed at the seaward end of the marsh and is renewed continually by uplift even in the absence of grazing, its continued presence in the upper salt-marsh is strongly dependent on the foraging activities of the geese. In their absence, rapid vegetational changes occur within 5 years leading to the development of a *Calamagrostis* - *Festuca* grassland in which herbaceous plants and willows grow. These swards are not as heavily grazed as swards of *Puccinellia* and *Carex*. The nutritional quality and digestion efficiency of the forage are lower than comparable data for *Puccinellia* - *Carex* forage (Gadallah and Jefferies 1995a,b).

Damage to Coastal Habitats

Coastal salt marsh plant communities

The coastal zone of the Hudson Bay lowlands and vicinity consists of a large number of salt marshes, the most notable of which are the marshes on the north

shore of Akimiski Island (Northwest Territories); Cape Henrietta Maria-Sutton River, Shell Brook, and Pen Islands (Ontario); Cape Churchill - La Pérouse Bay and the estuaries of the Knife and Seal Rivers (Manitoba); and the McConnell River - Wolf Creek system (Northwest Territories). However, most river estuaries have small areas of salt marsh adjacent to the mouth of the rivers and there are many small fringe salt marshes landward of barrier beaches. The marshes are dominated by two species, the stoloniferous grass, *Puccinellia phryganodes* and the rhizomatous sedge, *Carex subspathacea*, both of which are prime forage species of the lesser snow goose. Large breeding colonies are located at the geographical locations mentioned above where there is the strongest evidence of damage to vegetation. Some of these localities, such as the Cape Henrietta Maria-Sutton River salt marsh system are over 120 km in length.

All of these marsh systems show evidence of grubbing, although the scale of damage varies. Grubbing on Pen Island marshes is restricted, probably because they are covered by ice and snow until late in the spring, whereas at La Pérouse Bay, Cape Henrietta Maria, Akimiski Island and the McConnell River-Wolf Creek system grubbing is extensive ([Fig. 2.13](#)). At these localities the size of the grubbed patches increases each year and the graminoid vegetation fails to recover. Measurements of abundance of species based on 805 metres of transects across the salt marshes at La Pérouse Bay indicate that since 1985 approximately 70% of the salt-marsh graminoid swards have been severely damaged or destroyed by geese. On 5 of the 12 transects no vegetation remains (R. Jefferies, unpublished data).

The change in the state of the vegetation initiated by the geese acts as a trigger for a further series of changes that leads to increased destruction. The reduced area of salt marsh vegetation and the high numbers of goslings and adults result in intense foraging during the post-hatch period. The above-ground biomass of the heavily grazed swards may be only 10-15 grams dry weight (g dwt) per square metre (40 g dwt in undamaged grazed swards) (Cargill and Jefferies 1984, Williams *et al.* 1993). The effect of these foraging processes is to reduce the thickness of the vegetation mat (live and dead material) that insulates the underlying marine sediments from the air. These sediments were laid down when the Hudson Bay lowlands were part of the Tyrrell Sea. Rates of evaporation from the surface sediments increase and inorganic salts from the marine clays produce hypersaline conditions ranging from 32-120 g of dissolved solids per litre (32-120 ‰) (Iacobelli and Jefferies 1991, Srivastava and Jefferies 1995a,b; 1996). Experimental studies have shown that salinities above 32 ‰ (oceanic sea water) reduce the growth of the preferred forage plants, *Puccinellia phryganodes* and *Carex subspathacea*. This, together with the intense foraging, maintains open swards and hypersaline conditions and results in a positive feedback producing increased destruction of salt-marsh swards and desertification of the landscape (Srivastava and Jefferies 1996) ([Fig. 2.14](#)).

A group of species that may invade these grubbed sites are good ecological indicators of disturbance of swards by geese. *Salicornia borealis* and *Atriplex patula* var. *hastata* colonize bare sediments which are highly saline. These species do not grow in some localities such as the McConnell River-Wolf Creek system, but they are present at others, (e.g., Walker Bay, Central Arctic, B. Bromley, pers. comm.). Neither species is eaten by the geese; about 45% of the dry weight of plants of these species consists of salt. In late summer large areas of marsh appear reddish-purple in colour as *S. borealis* produces anthocyanin pigments at this time of year.

Within intertidal marshes a number of measures described above indicate ecosystem dysfunction. They include a low level of above-ground biomass, damage to pseudostems of graminoids and the presence of indicator species such as *Salicornia borealis*. At sites where the vegetation has been killed, bare mud flats remain. At some sites, such as on the foreshore between the north and south arms of the McConnell River, the remains of below-ground biomass of former *Puccinellia* swards are visible. Elsewhere the sediments are eroded, exposing underlying glacial till and marine gravels.

Damage to sand dunes and beach ridge plant communities

Beach ridges and dunes are widespread in coastal zones around the Bay. Lyme grass (*Elymus arenarius*) is an active colonizer of these dunes and ridges. Shoot pulling of developing shoots of this grass is widespread in early spring. The grass is no longer a common species at La Pérouse Bay. Some beach ridges where the grass was formerly abundant are now devoid of the species (B. Ganter, pers. comm.). In early spring these ridges are roosting sites for geese and dung heaps are deposited by the birds. The same scenario has developed where spring migrant Interior Canada geese and moult migrant giant Canada geese congregate near Cape Duncan, Akimiski Island, Northwest Territories (K. Abraham and R. Jefferies, pers. obs.). A flora characteristic of the overall disturbance by geese has colonized these degraded sites. *Senecio congestus*, *Matricaria ambigua* and *Rumex maritimus* invade; the leaves of the first species are eaten by the geese in very early spring. In addition, moss carpets (mainly *Bryum* species) are common on the tops of frost-heave hummocks, where the higher plant vegetation has been removed. In summer, the carpets dry out and the moss mat is blown away, exposing the underlying sand and gravels.

Damage to coastal meadow grassland and willow communities

In dry sites, immediately inland from the intertidal salt marshes, meadow grassland is widespread along the southern coast of Hudson Bay and in James Bay. The grassland is often colonized by *Salix brachycarpa* and *Salix myrtifolia*. The most common grass species include *Festuca rubra*, *Calamagrostis deschampsoides*, and to a lesser extent *Elymus arenarius*. These sites are

covered by tidal water on rare occasions. Grubbing of these grasslands, which have a thin veneer of organic matter on the surface of sediments, is common in spring. Both lesser snow geese and Canada geese grub the turf and remove grass roots and rhizomes. Where the grubbing of turfs extends to the base of willow bushes, the bushes die as a result of the hypersalinity and exposure of roots (Iacobelli and Jefferies 1991) ([Fig. 2.13c](#)). In some areas where the thin veneer of soil organic matter has been removed *Puccinellia phryganodes* and *Carex subspathacea* colonize the exposed saline sediment. Patches of these graminoids inland from the intertidal marshes are often indicative of secondary succession following goose disturbance. Further grubbing of these secondary swards can be expected.

Overall Comment

The descriptions given above indicate that the effects of the geese on vegetation development are not symmetrical. The geese interact with physical processes (i.e., the positive feedback described above) ([Fig. 2.14](#)), so that discontinuous and irreversible transitions in the serial stages of plant succession may occur (Hik *et al.* 1992). Intense grazing of the *Puccinellia*-*Carex* intertidal swards results in removal of apical meristems of leaves and shoots of dicotyledonous plants (*Plantago maritima*, *Potentilla egedii* and *Ranunculus cymbalaria*). This precludes further shoot growth for the remainder of the season. In effect, the geese reset the successional clock each year and delay successional processes. The species diversity (number of species per unit area) may be used as an indicator of intense goose foraging, particularly at sites close to the mean high water mark of spring tides. In the absence of grazing the plant assemblage switches to one dominated by *Festuca rubra* and species diversity increases rapidly (Bazely and Jefferies 1986).

Long-term destruction of sub-Arctic freshwater wetland vegetation by lesser snow geese

The Hudson Bay lowlands is one of the largest wetlands in the world. It provides food resources for several million migrating waterfowl, including the mid-continent population of lesser snow geese, the Eastern Prairie, Tall Grass Prairie, Mississippi Valley and Southern James Bay populations of Canada Geese, half of the Atlantic Brant population, and significant populations of pintails, black ducks, green-winged teal and mallards (Ross 1982, Thomas and Prevett 1982). When snow geese migrate north in spring they follow the coastline of Ontario, Manitoba and Northwest Territories northwards, staging just south of the retreating snowline. They feed primarily in fresh-water sedge meadows adjacent to coastal habitats. One of the most conspicuous types of damage that occurs in spring is shoot pulling. The birds forage intensively on the shoots of fresh-water sedges, particularly *Carex aquatilis*, but also *C. atrofusca*, *C. x flavicans* and *C. vaginata*. Later, during nesting, breeding birds also remove large numbers of shoots. At some localities shoot pulling has been intensive and

the effect is accumulative. In shallow ponds, where dense stands of *Carex aquatilis* were formerly present, the death of stands has created open ponds of standing water devoid of vegetation in which large amounts of organic matter and peat debris are mixed by surface winds (Fig. 2.15). The system is dysfunctional and the depth and mobility of the debris appear to restrict germination and seedling establishment of wetland species. The muds are anoxic and some ponds have remained in this state for a decade or more (Kotanen and Jefferies 1997). In saturated mossy areas, where sedge assemblages formerly occurred, the disappearance of sedges produces extensive moss carpets in which only scattered shoots remain (Fig. 2.16). Again the thick moss carpets, composed of *Drepanocladus uncinatus* and *Aulacomnium* species, appears to restrict seedling establishment of sedges (Kotanen and Jefferies 1997). Close to frost heave mounds, *Salix reticulata* and *S. arctophila*, together with *Potentilla palustris* and *Petasites sagittatus*, have grown across the moss carpet creating a new plant assemblage. The four latter species and the mosses are not eaten by the geese (Jefferies 1988a,b). This type of assemblage and moss carpets can be recognized at a number of goose colonies where sedges have been removed by geese (Kerbes *et al.* 1990; Kotanen and Jefferies 1997, K. Abraham, pers. obs.). Community development appears to have been altered irreversibly by the geese.

The large scale destruction of sedge meadow communities and the exposure of peaty sediments, or peat, can be seen in the McConnell River-Wolf Creek area (Kerbes, Kotanen and Jefferies 1990). In much of the coastal hinterland of string and flark (ridges and intervening wet zones) bogs and fens (oligotrophic / eutrophic mires), the geese have grubbed vegetation, exposing underlying peat over large areas. These dysfunctional systems have been called peat barrens (Kerbes *et al.* 1990) (Fig. 2.17). Plants of woody species, such as *Betula glandulosa* and *Empetrum nigrum*, which are confined to the strings, also die. At some sites erosion of the peat has occurred as a result of water movement (spring run-off) and chemical oxidation of peats as they dry-out in summer. Where this has occurred, the underlying glacial gravels and till are exposed. At present, examples of this kind of habitat damage along the west coast of Hudson Bay occur from the Tha-anne River north to the Maguse River, a distance of almost 200 km. The area is used by both breeding and staging birds (lesser snow geese).

Rates of destruction of vegetation

Most of the changes described in the above sections have occurred at La Pérouse Bay, Manitoba since 1978 when intensive studies of plant-herbivore interactions began there. Based on our knowledge of the changes in the vegetation, it is clear that this is an on-going process and that there are sites at La Pérouse Bay and elsewhere which show comparable changes in vegetation that occurred much earlier than 1978. How much earlier is very difficult to determine. Although the present colony at La Pérouse Bay was established in the late 1950s (Cooke *et al.* 1995), the area may have been a major staging

location prior to those years. What is different today compared to earlier times, is that the scale of destruction associated with the increase in the population size of lesser snow geese has increased in magnitude. Similar changes have occurred elsewhere along the coastline in response to the foraging activities of large numbers of birds (e.g., McConnell River, Cape Henrietta Maria, and Akimiski Island).

The damage to vegetation and soils of these coastal habitats is cumulative, although the same amount of damage does not occur each year. Prevailing weather conditions throughout the Hudson Bay region determine both migration rates of geese and which sites serve as staging areas in a given year. One approach that offers considerable promise for measuring rates of destruction of vegetation is the application of remote-sensing techniques, particularly the use of LANDSAT imagery. This approach has been used to detect vegetational changes since the 1970s at La Pérouse Bay and the north shore of Akimiski Island, and a similar study is underway to examine vegetational changes along the coast between the Knife and Seal Rivers. At La Pérouse Bay LANDSAT imagery based on spectral differences in the red and far-red bands between 1973 and 1993 indicates that the vegetation has been destroyed or severely damaged over an area of approximately 2400 ha (Jano, unpublished data) ([Fig. 2.18](#)). Much of the initial damage was on the beach ridges, dunes and in the salt marshes, but in the last 10 years the damage has extended to the fresh-water sedge meadows, as the birds seek alternative sources of forage. As a result, we are beginning to see an early stage in the development of peat barrens there, as described for the McConnell River-Wolf Creek area.

Estimates of damaged areas of coastal marshes

No formal estimate has been made of the total area of destroyed coastal marsh, or of the area of vegetation swards that have been partially damaged by the foraging activities of the geese. Such an analysis requires the following minimum information: (1) LANDSAT remote-sensing imagery of changes in vegetation from 1973 to the present along the entire Hudson Bay coastline; (2) the necessary ground-truthing of the vegetation and the preparation of a classified vegetation map; (3) calculation of damaged areas and ground-truthing of partially damaged areas in order to calculate this area; (4) Measurements of above-ground biomass at all sites.

Given that these data are unavailable at this time, the following, tentative estimates of the scale of destruction have been made. Long-term monitoring of ground transects in the inter-tidal marsh at La Pérouse Bay indicate the changes that have occurred to the vegetation since 1985. Approximately 35% of the vegetation swards have been destroyed and another 30% are so badly damaged, that they no longer provide a source of forage for the birds (because geese are present each summer recovery is impossible). In effect, two-thirds of the land base monitored in inter-tidal marsh is now non-productive. The

remaining 35% is “overgrazed”, such that damage to grass shoots is occurring. Independently, the results from the remote-sensing imagery show that approximately 2400 hectares of vegetation have been destroyed, or very badly damaged between 1973 and 1993 at La Pérouse Bay. Some of this area includes supra- and inland salt-marsh vegetation and sedge meadow vegetation. However, as most damage has occurred in intertidal areas (salt marshes and dunes/gravel ridges), an approximate estimate of 2,000 hectares of vegetation have either been destroyed, or so badly damaged that the vegetation is unproductive. This is equivalent (approximately!) to 65% of the former area of inter-tidal vegetation at La Pérouse Bay, as indicated above.

Observations of the state of inter-tidal salt marsh swards of *Puccinellia phryganodes* and *Carex subspathacea* along the entire coastline from Attawapiskat, Ontario to the Maguse River, NWT, together with measurements of above-ground standing crop (g m⁻²) give no reason to doubt that the estimates for La Pérouse Bay are applicable to other sites where snow geese feed during migration and breeding. In short, the “35%-30%-35%, pattern” discussed above can be applied to other sites. Major exceptions include the Pen Island marshes on the Ontario/Manitoba border where there is little damage and at river estuaries (e.g., Nelson, Albany) where large volumes of fresh water discharge, reducing the salinity and producing tall growth forms of both *Puccinellia* and *Carex* which are little grazed. Additional exceptions are small patches of salt marsh fringing beach ridges which are heavily grazed by Canada geese during brood rearing but remain productive. Andrew Jano (Ontario MNR, unpublished data) has estimated the area of intertidal marsh from the Kettle River (Ontario/Manitoba border) to Attawapiskat (Ontario, James Bay) in contiguous 5 km segments of coastline. The total area is 35,329 hectares, including 2,000 hectares for the north coast of Akimiski Island. Figures for supratidal marsh of the same area are also available but comparable figures have not been calculated from remote sensing imagery yet for Manitoba and NWT. In Manitoba, the area of grazed *Puccinellia-Carex* (i.e., intertidal) salt marsh is estimated to be 14,500 hectares and for the NWT as far north as the Maguse River, the estimate is 5,000 hectares (R. Jefferies, unpublished data). Hence, out of a total of 54,829 hectares of intertidal salt marsh for the entire coastline it is estimated that approximately 35,638 hectares are no longer productive and the majority of the remaining areas of salt-marsh swards are heavily utilized. It should be emphasised that these figures for the area outside La Pérouse Bay are very provisional and they do not include supra-tidal marshes.

Similar estimates of damage to sedge meadow-fen vegetation cannot be made at this time as the extent of damage is very poorly known.

GREATER SNOW GEESE IN BREEDING, STAGING AND WINTERING AREAS

The single population of this sub-species breeds from northern Baffin Island and northwards and birds feed predominantly on sedges and grasses growing in moss-covered fens and in uplands during the summer. There is evidence of changes in habitat use by snow goose families, possibly in response to food depletion in the grass and sedge fens which are their preferred habitat. These are habitats where there is a well developed organic substratum, unlike the situation on the intertidal flats of the Hudson Bay coast. Parallels can be made between the two subspecies and their effects on vegetation, but there are also differences, primarily related to the use of different species as a prime source of forage.

Damage to Coastal Habitats in the Wintering and Staging Areas

Prior to the 1960s the geese fed almost exclusively in freshwater tidal marshes dominated by the bulrush, *Scirpus americanus*, particularly in the marshes of the St. Lawrence River (Giroux and Bédard 1987, Reed 1989). Smith (1983) reported that greater snow geese altered the species composition of salt marshes on the wintering grounds in North Carolina. The birds grazed intensively on *Spartina alterniflora* and on *Spartina patens* and the above-ground biomass was severely reduced (Smith and Odum 1981, [Fig. 2.20](#)). However, the vegetation was not eliminated and full recovery of the latter species occurred in exclosures which were protected for two growing seasons after grazing ceased. *Scirpus robustus* invaded heavily grazed patches of *Spartina alterniflora*. Stands of *Scirpus americanus* were unaffected by grazing, the percentage cover in grazed and ungrazed areas was not significantly different. *Eleocharis* species were only present in grazed sites. Of course, the geese grazed only during the period when the marsh plants were dormant, hence the effects of grazing and rhizome grubbing were not likely to be as severe as when active growth was occurring. Nevertheless, grazing/grubbing led to a decrease in net below-ground production and a change in species composition.

Formerly, staging in the St. Lawrence estuary occurred almost exclusively in the *Scirpus americanus* marshes, and even today, with many more geese and an expanded range, those marshes are of critical importance. Vigorous grubbing by the geese removed an estimate 74% of the underground biomass of *Scirpus* in one year in a major marsh area, however, no long term trend in abundance of the plant occurred (Reed 1989). In another marsh, it was demonstrated that net above ground primary production of *Scirpus* was lower in areas exposed to heavy grubbing by geese than in areas protected from grubbing (Giroux and Bédard 1987) but the heavily grubbed areas were maintaining their production (albeit at a lower-than-potential level) over the long term (Reed and Giroux, unpublished data). Expansion of the staging area downstream led to geese feeding on salt-marsh vegetation, including *Spartina alterniflora* and *Spartina patens*. Although marshes continue to be used as roost sites (Gauthier *et al.* 1988), the low abundance of *Scirpus americanus* and the high extraction cost and low energy

return associated with *Spartina* roots has led to the birds feeding in agricultural land (Bédard and Gauthier 1989). The rhizomes of bulrush (*S. americanus*) are still an important component of the diet, but there are indications that demand is outstripping the regrowth potential of stands of bulrush, and that soft mudflats are replacing former stands of bulrush. A similar situation exists in the Fraser Delta in British Columbia, where lesser snow geese eat a substantial proportion of the total rhizome of each plant of *Scirpus* (Burton 1977). In addition, the geese there are increasingly foraging for waste crops on agricultural land (potato fields, corn and wheat stubble fields).

Damage to Agricultural Crops

Most of the reported damage to agricultural land in the USA by greater snow geese is associated with small grain crops, particularly winter wheat. Damage can result from a variety of causes but it includes removal of seedlings, grazing of plants, and the loss of seed heads (Anonymous 1981, Hindman and Ferrigno 1990). In some areas, the persistent foraging by geese has led to reduced wheat yields. The birds also glean grain from old fields of corn (*Zea mays*) and soybean (*Glycine max*) (Reed 1991). A crop damage insurance program began in Québec in 1992. Costs of reported damage to hay crops by GSGO in Québec from 1992-1995 are shown in Table 2.1.

Most agricultural land adjacent to the marshes in the St. Lawrence River is managed for hay production based on a 4-6 year rotation system with oats/barley, *Phleum pratense*, *Trifolium pratense* and *Medicago sativa*. In spring, geese graze the new green growth which is mostly *Phleum* (timothy grass). Heavy grazing on this growth and that of other forage species can significantly reduce hay yields at first harvest (Bédard *et al.* 1986, Reed and Cloutier 1990) which occurs from mid- to late-June (Reed 1991). This is approximately 3 to 6 weeks after the northward migration of geese from the area. In the Montmagny area where the grazing is particularly intensive, a mean loss of 14% in hay yield was recorded in old and new hay fields in 1980. By 1985 goose usage had tripled and hay losses at harvest had doubled (Bédard and Lapointe 1991). Yield loss is not uniform across the entire area but is concentrated in a few individual fields, hence the loss is disproportionately high for a small group of farmers. Gauthier and Bédard (1991) have experimented with forage mixtures which are less palatable to the geese. Among legumes, *Trifolium pratense* ranked highest and *Lotus corniculatus* lowest in preference. Among grasses, *Phalaris arundinacea* (canary grass) was the preferred species followed by *Dactylis glomerata*, *Bromus inermis* and *Phleum pratense*. They conclude that the substitution of *Trifolium* with *Lotus* would reduce the attractiveness of hay fields to snow geese.

Table 2.1. Crop damage by greater snow geese in Québec (data courtesy of Michel Lepage, Ministère de l'Environnement et de la Faune du Québec).

	1992	1993	1994	1995
Claims for goose damage	\$ 466,600	\$ 211,500	\$ 500,000	\$700,000
Compensation paid	\$ 373,270	\$ 169,200	\$400,000	\$ 560,000
Administrative cost	\$ 139,200	\$ 72,700	\$ 193,200	\$ 186,600

Preferred Forage Species on the High Arctic Breeding Grounds

Much of the information discussed below is based on the results of G. Gauthier and his group working on Bylot Island, NWT, where there is a large breeding colony of greater snow geese numbering 27,500 breeding pairs in 1993 (Reed and Chagnon 1987; Reed *et al.* 1992, and A. Reed, unpublished data).

Grazing by geese has had a major impact on the above-ground biomass of forage graminoid species and the effect of the geese on the vegetation has increased in recent years (Gauthier *et al.* 1995). Although *Dupontia fisheri* is the dominant plant in moss covered fens in which family groups of greater snow geese feed, the impact of goose grazing was more severe on *Eriophorum scheuchzeri/angustifolium* than on *Dupontia*. Peak above-ground biomass in ungrazed areas averaged 33 g dwt/sq m. In all years of a three-year study, it was estimated that geese consumed from 65-113% of the cumulative net above-ground primary production (NAPP) of *Eriophorum* species and 30- 78% of the cumulative NAPP of *Dupontia*. Grazed plants were able to grow new foliage, but grazing did not enhance NAPP, unlike at La Pérouse Bay where swards of *Puccinellia phryganodes* show increased NAPP following defoliation (Cargill and Jefferies 1984).

It is likely that this pattern of grazing is common in the high Arctic. Again, there are indications that with the increasing number of birds the swards may not be able to regenerate and foraging areas will become moss carpets. On the Tundra of the Academy on Wrangel Island this has occurred in the vicinity of shallow, thermokarst lakes (R. Jefferies, per. obs.). However, in general, there does not appear to be the level of damage in the high arctic that characterizes the coastal areas of the subarctic Hudson Bay lowland.

STATUS OF HABITAT AT SELECTED BREEDING AND STAGING SITES

The above accounts of the damage are necessarily based on longer term studies of systems where both observational and experimental evidence are irrefutable. Studies are now under way on a wider scale, yet there is an immediate need to answer questions about the magnitude and distribution of the problem of high populations and damaged Arctic and sub-Arctic coastal ecosystems (i.e., how much habitat is there and in what condition is it?).

The range of geese in Arctic North America is vast and a comprehensive inventory of the status of habitat at all the important sites is unavailable. Here, we briefly describe conditions at several major breeding or staging sites, with histories of visitation spanning 30-40 years, and all visited within the last 5-10 years. The order of presentation is arbitrarily from south to north and east to west ([Fig. 2.2b](#)).

Akimiski Island, NWT

Vegetation damage to the intertidal area along much of the north shore of Akimiski Island is extensive. Mudflats have replaced swards of *Puccinellia phryganodes* and *Carex subspathacea* and only patches of vegetation remain. The *Festuca rubra* and *Calamagrostis deschampsoides* swards in the upper intertidal zone also are being increasingly grazed and grubbed. Brackish and fresh-water graminoid vegetation immediately inland from the upper limit of spring tides is grazed heavily in summer and shoot pulling is common in spring. Bare peaty areas occur as a result of foraging activities by both lesser snow geese and Canada geese. Dead willow stands occur locally in grubbed areas. Extensive areas are now covered by non-forage plant species, including *Glaux maritima* and *Senecio congestus*. Fresh-water sedge meadows show limited signs of damage, but no close examination has been made.

The vegetation in the south-east coastal zone of the island also has been badly damaged by migrating and molting Canada geese. The graminoid cover there has been removed and an extensive moss carpet together with *Senecio congestus* and *Spergularia marina* has replaced much of the brackish intertidal vegetation. Large areas of hypersalinity are marked by extensive stands of *Salicornia borealis*. The south shore of the islands has a steeper gradient, and hence less marsh. In general, it appears to be in good condition, but goose use is limited compared to the north shore.

West coast of James Bay, Ontario

Damage to vegetation as a result of grubbing is localized in salt marshes which occur in embayments or landward of barrier beaches. In general, grubbing is more evident north of Attawapiskat River than south of it. Intensive spring foraging by staging snow and Canada geese has been documented for areas north of Ekwan Point as far as the Lakitusaki River (Wypkema and Ankney 1979, Prevett *et al.* 1985, Hudson Bay Project, unpublished data). The brackish /

freshwater marshes are dominated by *Carex aquatilis*, *C. paleacea* and *Hippuris tetraphylla*. The presence of ice and deep melt water in spring along the shoreline, the extensive spring and autumn hunting carried out by people from coastal settlements and the absence of large breeding colonies of lesser snow geese has resulted in only localized damage to vegetation.

Cape Henrietta Maria, Ontario

The Cape Henrietta Maria region contains an extensive area of intertidal salt marsh that has been severely grubbed and heavily grazed. Inland from the intertidal zone are extensive moss carpets, particularly in the region of the Cape itself. The conditions prevail on the James Bay coast as far south as Hook Point. Between the Cape and the Sutton River to the west, large grubbed areas, degraded salt marsh swards and moss carpets dominate the coastal zone. The salt marshes immediately west of the Sutton River are in relatively good condition, although there are indications of increased grubbing of these marshes. In 1996, the western perimeter of the breeding colony was east of the Sutton River. Tundra areas inland of the inter-tidal areas have extensive fresh-water sedge meadows dominated by *Carex aquatilis*. These show moderate to heavy grazing by older broods up to 8-10 km from the coast. However, intensive damage, such as the development of peat barrens, has been noted only near the core of the large breeding colony.

The Hudson Bay Coast of Ontario

The stretch of coastline from Sutton River west to the Ontario - Manitoba border shows a diverse geomorphology. Much of the coastline consists of barrier beaches, landward of which are small fringe salt marshes that are both grubbed and heavily grazed by Canada geese and lesser snow geese. Relatively small, but high density colonies of nesting lesser snow geese occur in the vicinity of the more extensive salt marshes east of Winisk River, at Shell Brook and at the Pen Islands. The vegetation at the latter site which is large (20 km x 5 km) is in good condition, possibly protected by deep snow and ice in spring. At the other locations and at the estuaries of the rivers which drain the Hudson Bay Lowlands some damage to the *Puccinellia* - *Carex* swards is evident.

The Hudson Bay Coast of Manitoba

The coastline of Manitoba between the Black Duck River in the east and Rupert Creek at the southern end of the Cape Churchill Peninsula has no large colony of breeding lesser snow geese. The area is a major staging region for lesser snow geese and Canada geese in spring. Between the border with Ontario and Cape Tatnum, the coastline consists largely of barrier beaches with heavily grazed/grubbed fringe salt marshes. The vegetation along the remainder of the coastline is dominated by the outflow and mineral sedimentation from the Nelson and Hayes Rivers. This produces freshwater/brackish conditions and rank growth

of vegetation which is ungrazed. Staging birds pull shoots in the sedge meadows inland from the coast. There is some moss carpet development and many bare areas in which loose sediment is present on the surface.

The Cape Churchill Region and La Pérouse Bay, Manitoba

The expanding population of lesser snow geese at La Pérouse Bay has resulted in substantial changes to all intertidal habitats. No extensive *Puccinellia-Carex* swards remain and large areas of dead willows are present in the coastal zone. In addition, nearly all shoots of *Carex aquatilis* are grazed up to 10 km from the coast. In the vicinity of the coast extensive moss carpets are present. Indicator plants of severe disturbance and hypersalinity, such as *Senecio congestus* and *Salicornia borealis* are widespread. In 1996, birds nested from Rupert Creek to Christmas Lake beach ridge and densities of nests at some sites exceeded 2500 km⁻².

Knife and Seal Rivers, Manitoba

The extensive braided estuaries of the Knife and Seal Rivers have staging, breeding and post-hatch populations of lesser snow geese and Canada geese. There are a number of *Puccinellia-Carex* marshes that are badly grubbed and damaged. Moss carpets have developed where *Carex aquatilis* shoots have been removed.

Tha-Anne River to the Maguse River in the NWT on the west coast of Hudson Bay, NWT

The coastal inter-tidal salt marsh has been replaced by mudflats throughout the entire coastal strip, except at Wolf Creek. Eutrophic, mesotrophic and oligotrophic sedge communities have either been heavily grazed or replaced by peat barrens for distances up to 10 km inland from the coast. At some sites, the peat has been eroded to expose glacial gravels.

Southampton Island, NWT

Although quantitative vegetation surveys have not been carried out on Southampton Island in relation to the effects of foraging by geese, reports from biologists who have visited the breeding colonies of lesser snow geese indicate that there is widespread shoot-pulling of sedges, heavy grazing of shoots of *Carex aquatilis* / *stans* and *Arctophila fulva* and the presence of bare peat areas and moss carpets. At Boas River, formerly extensive salt marshes reported by T. Barry are badly grubbed and reduced to remnant areas. These changes in the vegetation are of particular interest as breeding colonies of Brant, Canada and lesser snow geese are in close proximity to each other. There are virtually no graminoid areas on the southern two-thirds of the island that are not used by broods of snow geese and the other three goose species. Snow goose broods

now travel from the East Bay nesting areas all the way westward to the village of Coral Harbour itself, a distance of up to 60 km (K. Abraham, pers. obs).

Southwestern Baffin Island, NWT

This area along the shores of Foxe Basin contains the locations of the first documented lesser snow geese nesting (in the 1920s) and has been occupied continuously since. Several large colonies of lesser snow geese that breed in the coastal marshes and move inland along river valleys to forage on fresh-water graminoids. Again formal vegetation studies of this area have not been done, but damage to salt marshes is evident (D. Caswell, pers. comm.). Examination of photographs indicates widespread destruction of coastal vegetation by geese (grubbing) and the development of moss carpets in the river valleys of the uplands. The lack of quantification is unfortunate because the area may hold as many as one-third of the mid-continent breeding population (D. Caswell, unpublished data).

Bylot Island, NWT

In some areas, there has been deterioration of vegetation in recent years as a result of the foraging activities of a colony of greater snow geese. The birds forage on a range of graminoids, in particular, *Dupontia fisheri*, *Eriophorum angustifolium* and *Eriophorum scheuchzeri* that grow on an organic substratum rather than a mineral substratum. The death or poor growth of individual tussocks/shoot systems following intense foraging has led to the development of sparse growth of graminoids, and the increase of moss. The studies of G. Gauthier and associates show, in prime brood rearing areas: 1) a high impact of grazing, 2) regrowth of plants after grazing and 3) lower production of plants in heavily grazed habitats (Gauthier *et al.* 1995, Gauthier *et al.* 1996). However, the long-term ability of the plants to recover is not yet affected because, when geese were excluded, production of *Eriophorum* tripled after four years (Gauthier *et al.* 1996).

Queen Maud Gulf, NWT

Extensive studies of the growth and geographical expansion of the colonies of Ross' and lesser snow geese in this region indicate that the birds have expanded beyond prime nesting colony sites, especially where lakes occur, to marginal mainland fresh-water tundra sites. The birds forage in both coastal and inland marshes and travel large distances (over 60 km, R. Alisauskas and S. Slattery, unpublished data) to suitable brood rearing habitats. A number of the vegetation changes reported for the west coast of Hudson Bay occur here, including extensive areas of peat barrens that can be detected from satellite imagery (LANDSAT).

Banks Island, NWT

Formal vegetation studies in relation to the effects of goose grazing are absent. However, the types of changes to vegetation indicated above as a result of goose grazing are expected to occur and can be seen on recent photographs of the area.

North Slope of Alaska, USA

The relatively small breeding colony of lesser snow geese on Howe Island, Sagavanirktok River (<250 pairs) is unlikely to have deleterious effects on the vegetation at this point. However, fall staging of snow geese from the western Canadian Arctic occurs in fresh-water tundra wetlands on the coastal plain. No assessment of damage has been made.

Wrangel Island, Russian Federation

Damage to vegetation at the nesting site in the uplands is minimal and confined to local grubbing. On the coastal Tundra of the Academy there is very heavy grazing of shoots in the vicinity of lakes (<250 m) and moss carpets or swards of *Petasites sagittatus* (arctic coltsfoot/heliotrope/ butterbur) are common.

IMPACTS OF HIGH POPULATIONS ON GEESE AND OTHER FAUNA

Effects on the Geese Themselves

Lesser snow geese from Hudson Bay have experienced declines in adult and gosling body size, gosling survival (Cooch *et al.*, 1991a,b; Williams *et al.* 1993) and increases in parasites (Rockwell *et al.* 1994). Greater snow geese have declined in body size (Reed and Plante 1997). J. Leafloor (unpublished data) and M. Hill (unpublished data) have found that adult and gosling *interior* Canada goose from Akimiski Island, NWT exhibit morphological variation from area to area that is consistent with the hypothesis of reduced forage resources resulting from high populations of geese.

Effects on Other Birds

The effects on other birds have not been studied. Nesting birds in the vicinity of goose colonies where severe damage has occurred experience direct loss of nesting habitat through the destruction of sedge, grass and low shrub associations. In addition, the changes to soil salinity and decomposition processes likely result in significantly altered microfaunal changes resulting in a loss of forage resources. Preliminary findings (B. Milakovic and R. Jefferies,

unpublished data) suggest that aquatic invertebrates may be less diverse and less abundant in ponds in areas of degraded vegetation.

Gratto-Trevor (1994) monitored local nesting populations of Semipalmated Sandpipers (*Calidris pusilla*) and Red-necked Phalaropes (*Phalaropus lobatus*) at La Pérouse Bay, Manitoba. Nesting pairs of both species have declined dramatically in habitats traditionally occupied by relatively high densities of lesser snow geese for nesting and brood rearing over the last 30 years. Impacts of the growing snow goose colony on habitat quality of these shorebirds was cited along with weather and predation rates as possible explanations. The Yellow Rail (*Coturnicops noveboracensis*) was formerly abundant at La Pérouse Bay, but has not been encountered there recently (R. Rockwell, unpublished data). Other shorebirds, ducks (e.g., American Wigeon, *Anas americana*, and Northern Shoveler, *Anas clypeata*) and passerines, (e.g., Lapland Longspurs, *Calcarius lapponicus*) are likely candidates for similar negative interactions because they share either nesting or brood rearing habitats. Some species appear to be utilizing degraded environments. For example, where willows have died and little vegetation remains, Semipalmated Plovers (*Charadrius semipalmatus*) breed. The scale of the problem and associated level of risk to the broader populations requires intensive study, including some calculation of the proportion of total range of the species affected by goose damage. It is clear, however, that the interaction is dynamic, and the rapid occupation of new areas by geese increases the threat to other species even as the effects are being calculated.

GEESE IN RELATION TO PEOPLE

A full review of human interactions with growing populations of geese is beyond the scope of this report. Here we discuss consumptive uses of geese, primarily lesser snow geese and Canada geese by aboriginal people in Canada ([Table 2.2](#), [Fig. 2.21](#), K. Dickson, CWS data). Waterfowl in general are important in the provisioning of aboriginal communities with meat. Snow geese and Canada geese are particularly important over a broad area. Clearly, however, the importance numerically is greatest among Cree communities of the Hudson Bay Lowland in southern Hudson Bay. The communities in the Ontario portion have been surveyed periodically for over four decades (see below).

Aboriginal Land Use in the Hudson Bay Lowland

A land-based economy remains a major component of the mixed economies of most aboriginal communities in the lowlands of southern Hudson Bay and western James Bay region (Berkes *et al.* 1994, 1995). Within this region of Ontario, the Cree place considerable emphasis on land use in relation to self-governance, and for strengthening land use and hunting traditions in

communities. The population there is concentrated in Moosonee and eight First Nation Communities, Moose Factory, Moccreebec, New Post, Fort Albany, Kashechewan, Attawapiskat, Peawanuck and Fort Severn ([Fig. 2.22](#)). All settlements are members of the Mushkegowuk Harvesters Association who share the coastal region and use the same wildlife populations (Berkes *et al.* 1995). In addition, in the Manitoba portion of the Hudson Bay lowlands, the town of Churchill has a Cree population with its own Council, and the First Nation community of Shamattawa has a history of seasonal use of coastal areas for wildlife harvesting. In Québec, the Cree communities of eastern James Bay share many of the cultural traditions of the Ontario James Bay Cree, including heavy reliance on waterfowl, and their regional economies are similar (James Bay and Northern Québec Native Harvesting Research Committee 1976, Boyd 1977).

The information given below is based on mapping of harvest sites and the collection of data from hunters among the resident aboriginal population in the Ontario portion of the region (Prevett *et al.* 1983, Thompson and Hutchison 1989, Berkes *et al.* 1994, 1995) and does not include Manitoba and Québec portions of the Lowland.

Major harvesting activities

Of the major wildlife harvesting activities, the spring waterfowl hunt attracted about 14,000 person-days of harvesting effort in 1990 and the fall waterfowl hunt about 10,000 person-days, the most recent year for which data are available (Berkes *et al.* 1994). Most harvesters spent 10 to 50 days per year hunting. Harvest of Canada geese dominates the spring hunt and harvest of lesser snow geese dominates in the fall, with some variation between localities. In spring, geese are hunted along inland drainage basins as well as on the coast and the season is shorter compared to that in late summer and fall. Hunters from Kashechewan, Fort Albany and Attawapiskat stay close to the coast in spring but range more extensively in fall. There is considerable overlap in community hunting areas. Overall, two communities, Moose Factory and Kashechewan, accounted for over half of the hunting effort and most communities spent more time waterfowl hunting than any other hunting activity.

Native Goose Harvest in the Hudson Bay Lowland of Ontario

The reported number of Canada geese killed in 1990 was 40,676 and the figure for lesser snow geese was 38,022. Projected estimates of total number of birds taken in the region by First Nations

people were 56,536 and 55,076, respectively, for the two species (Berkes *et al.* 1994). Of all hunters reporting, 80%-90% participated in the waterfowl hunt in both seasons (Berkes *et al.* 1994, Prevett *et al.* 1983). The recent estimates of kill and participation are similar to those of a decade earlier (48,977 Canada geese

and 50,146 snow geese, Thompson and Hutchison 1989). The estimates for Canada geese are higher than those from the mid 1970s (range 17,577-23,508 for 3 years; Prevett, Lumsden and Johnson 1983) and also higher for snow geese except in one year (range 31,284-50,334 over the same 3 years). Estimates of snow goose kill are also higher than reported for the 1950s (35,000-40,000; Hanson and Currie 1957). Increased harvests are primarily due to an increase in the aboriginal population of the Lowland. The harvest per hunter (often equated with household) has stayed very similar over the decades. The mean annual waterfowl kill per hunter was nearly 100; for snow geese it averaged 37 per hunter over the whole coast, with variations among communities (Prevett *et al.* 1983). The mean waterfowl kill per harvester was 93.7 in 1990 (Berkes *et al.* 1994); for snow geese it was 38.7 (Table 2.2).

It is interesting to note that the harvest of snow geese, while higher, has not risen proportionately with the increase in the mid-continent population from which the birds are taken. This may indicate that increasing aboriginal harvest for management of high populations (Johnson 1997) might be difficult to achieve. Hunters from the James Bay communities have stated that the fall snow goose hunt is poorer than it used to be; they complain of fewer birds being present in James Bay (in contrast to the known growth of the meta-population) and also that flocks are more difficult to decoy. Disproportionate changes in populations around the Hudson Bay region (i.e., higher in the west) or changes in migration routes could explain an observation of fewer geese in James Bay. The extreme south end of James Bay historically provided major staging habitat for reproductively successful snow geese (i.e., families with young) (Prevett *et al.* 1982). A partial explanation for the elders' observations of more difficult hunting may be that flocks now generally have a smaller proportion of young (because of high pre-fledging and immediate post-fledging gosling mortality); thus they would react differently to decoys. Elders from Peawanuck and Moose Factory have also related to us that geese are thinner and taste different (worse) than in the past. This thinning may be a result of habitat degradation which influences accumulation of nutrients and the taste difference may be related to depletion of primary forage species and use by geese of other plants.

Estimated Food Value of the Native Harvest in the Hudson Bay Lowland of Ontario

In the region as a whole, the estimated edible weight of Canada geese killed was 120,000 kg/yr and for lesser snow geese the value was 88,000 kg/yr (Berkes *et al.* 1994). The protein equivalent is approximately 24 g protein 100 g⁻¹ meat. The protein available from all bush foods was estimated to be 97 g per adult per day in the region (Berkes *et al.* 1994). The replacement value of waterfowl in 1990 was between \$8.14 and \$11.40 per kg of edible meat in stores (poultry) in settlements.

The tradition of wildlife harvesting appears to be very strong in the region and represents a major contribution to the overall regional economy and cultural sustainability of the Hudson Bay Lowland Cree. A similar economy exists in James Bay and Ungava, Québec and although magnitude of aboriginal waterfowl harvest is much less elsewhere, it is no less important culturally and in terms of food value.

Harvest in Canada and the United States

Trends in harvest and hunter numbers are shown in [Fig. 2.9a](#) for areas in the central United States and Canada where mid-continent lesser snow geese are hunted. As noted, the number of geese harvested and the harvest rate have declined in both countries as the population of geese has increased. Many factors are cited for the declines, including large flocks, flocking behavior that makes decoying difficult, a preponderance of experienced adults and a wealth of choices of feeding areas. Harvest per hunter has increased, particularly in the Central Flyway and this has compensated somewhat for the decline in hunter numbers, but not sufficiently to keep harvest rate from declining.

SUMMARY OF ISSUES

Are There Too Many White Geese?

The answer differs for each white goose population and on whether a social/economic or biological perspective is required. Most populations of LSGO, ROGO and GSGO continue to grow, and at the landscape level (i.e., the continental scale) the system has the capacity to support further population growth. However, sufficient capacity at one time in the annual cycle (non-breeding) and in one region of their range (migration and winter) does not mean that all places on all occasions have sufficient capacity for sustained growth of populations. While the wintering areas appear to have the human-induced biological capacity to support the current high populations, the breeding grounds do not. The growth and decline of the McConnell River and other colonies of West Hudson Bay is a prime example. Staging, nesting and brood-rearing habitats in the eastern and central Canadian Arctic and some temperate staging and wintering areas show measurable short-term deterioration and cumulative degradation. The resource deficit caused by this degradation will not be easy to correct as recovery of these habitats likely will take decades.

A combination of direct and indirect human-generated factors are at the root of the twentieth century increase of Arctic geese. These major factors, such as agricultural practices and climate change, are not the responsibility of wildlife

management agencies. Some conservation programs of these agencies (e.g., refuges, hunting regulations) have had an important synergistic effect on the increase in population size, (e.g., by expanding areas of suitable habitat for the birds and by dispersing geese over wide areas). Nevertheless, these agencies are left with the primary responsibility of changing the direction of population growth, if the damage caused by geese is deemed publicly unacceptable. Although agricultural economics is beyond direct wildlife agency control, it would be prudent to engage in discussions with the agricultural community about alternative agricultural practices less beneficial to geese because they play a pivotal role in the phenomenal success of geese. As long as cultivation of rice, corn and other cereal grains used by geese is economically profitable and agricultural practices remain unchanged, the output of these agro-ecosystems will allow continued population growth of geese.

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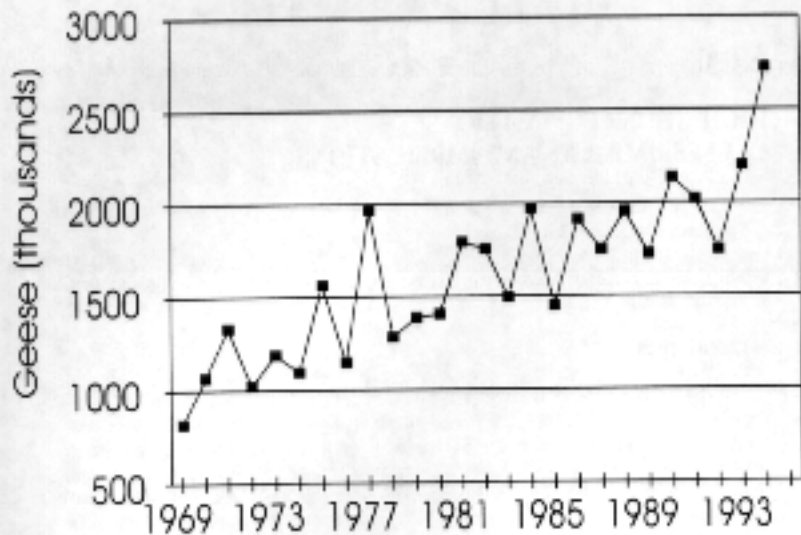
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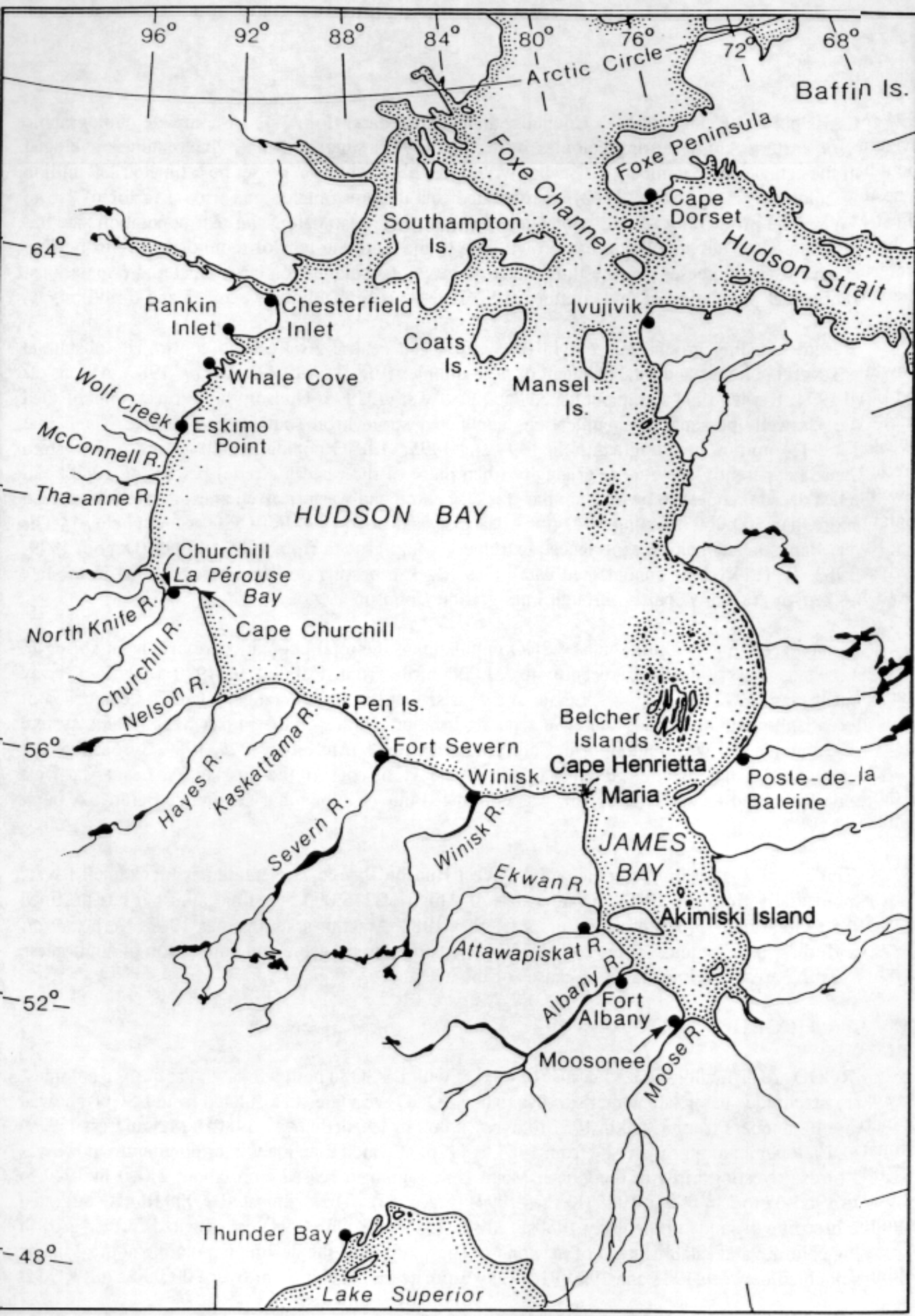
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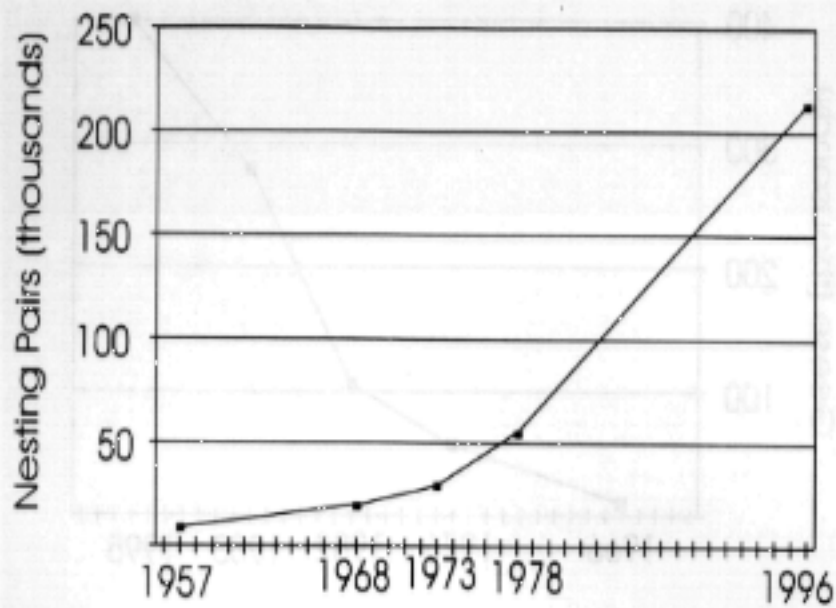
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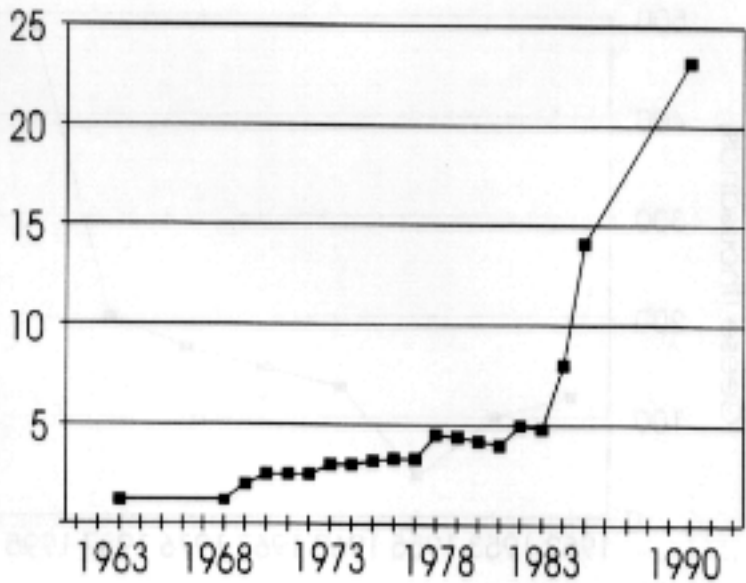
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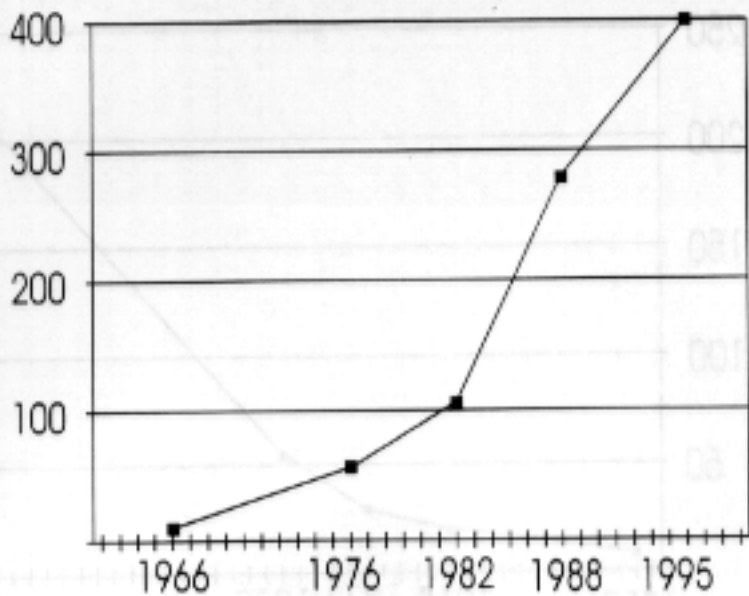




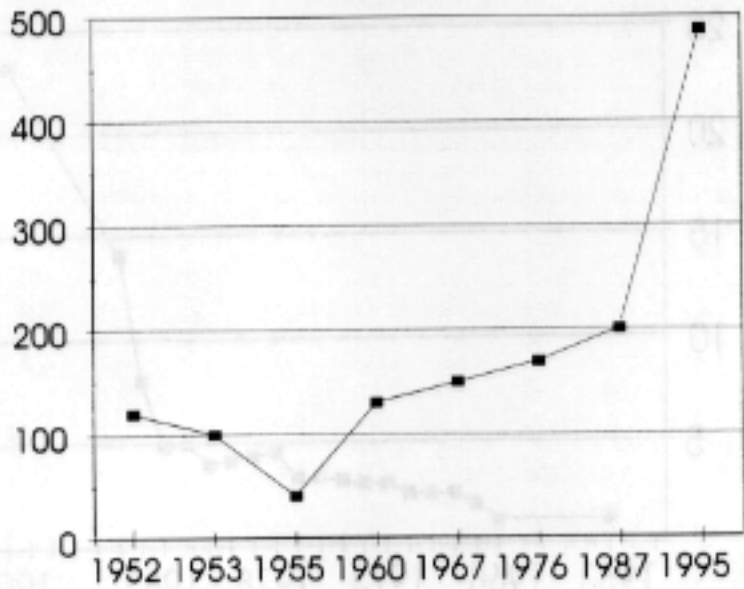
Nesting Pairs (thousands)



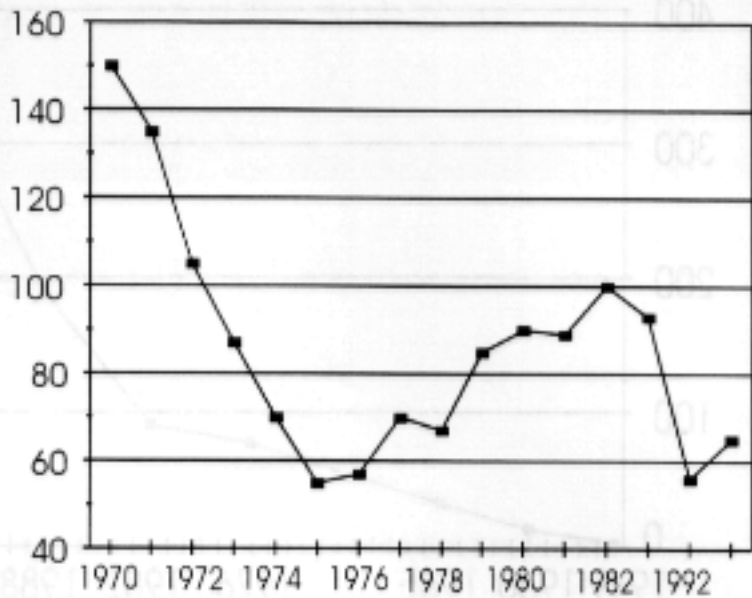
Geese (thousands)

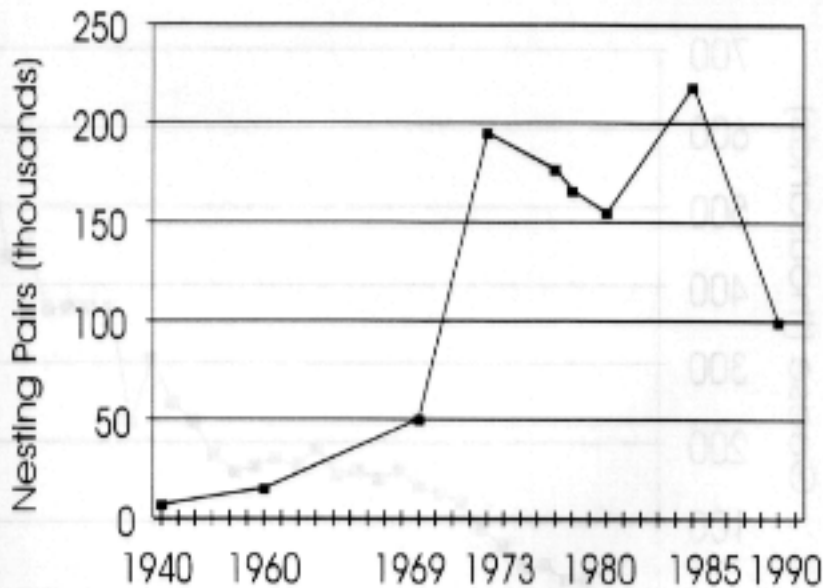


Geese (thousands)

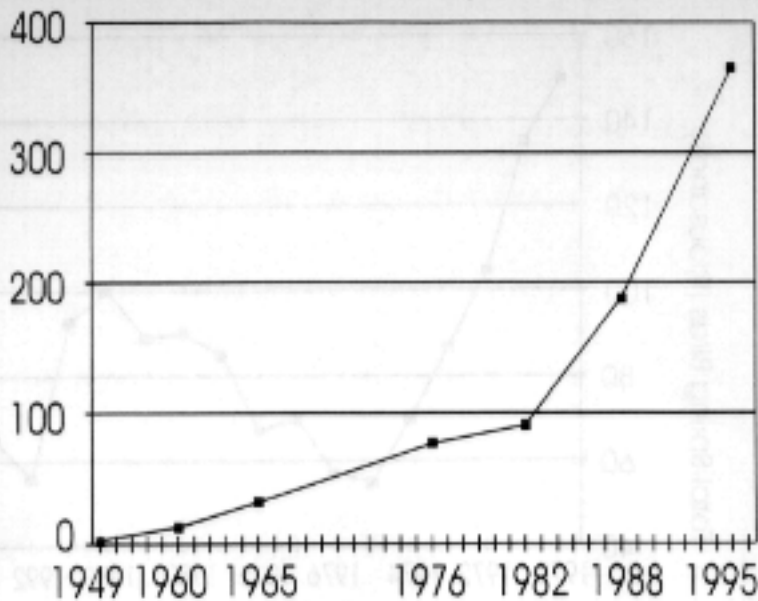


Total Spring Birds (thousands)

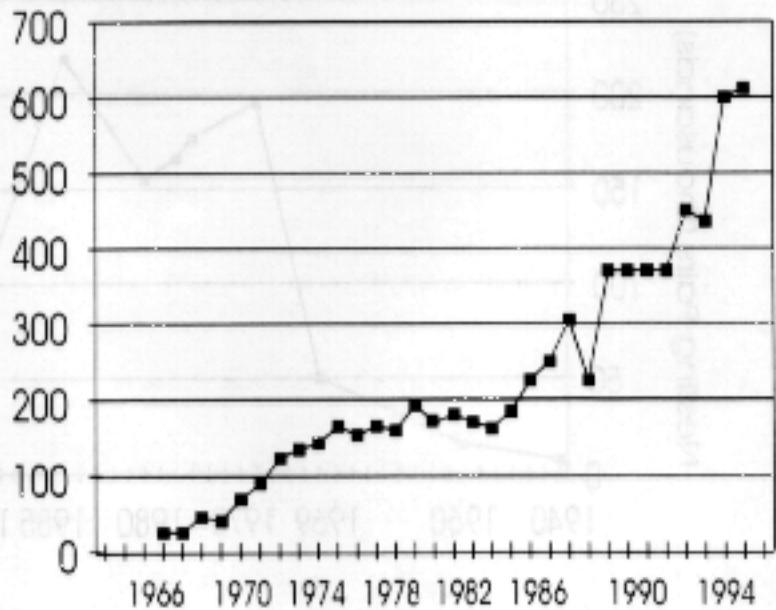


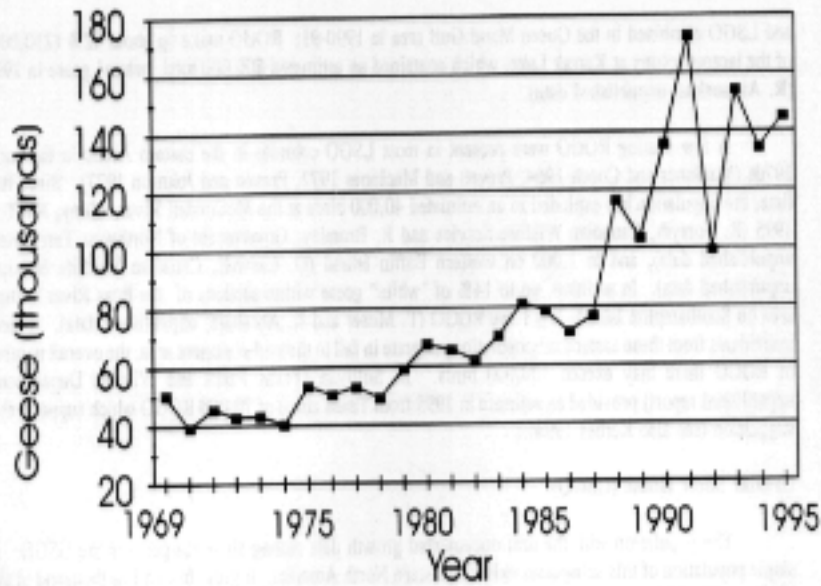


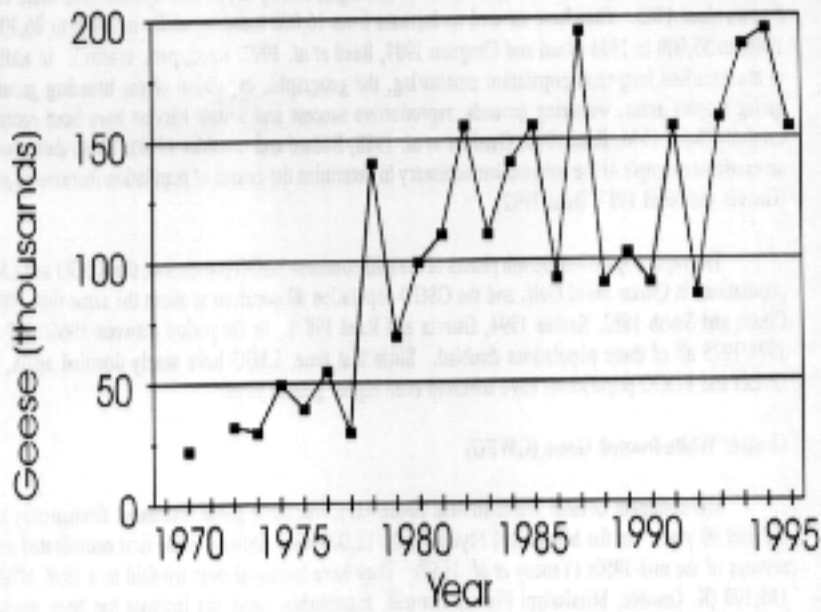
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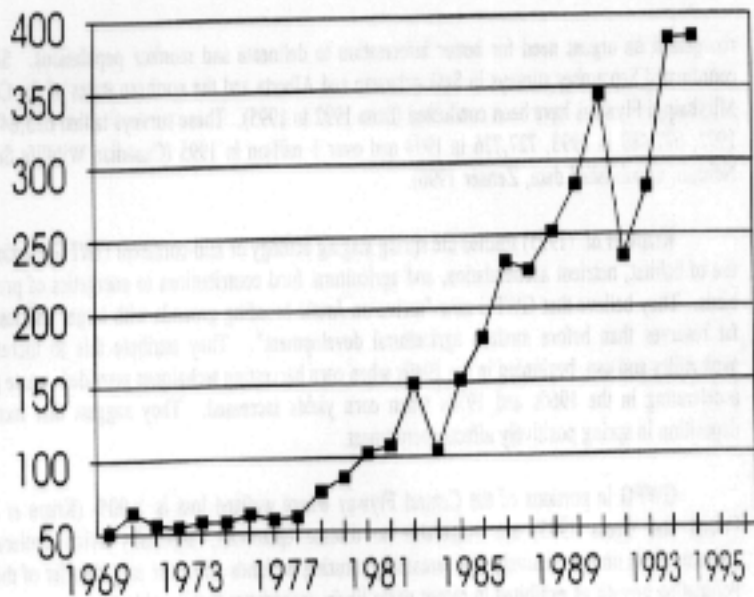
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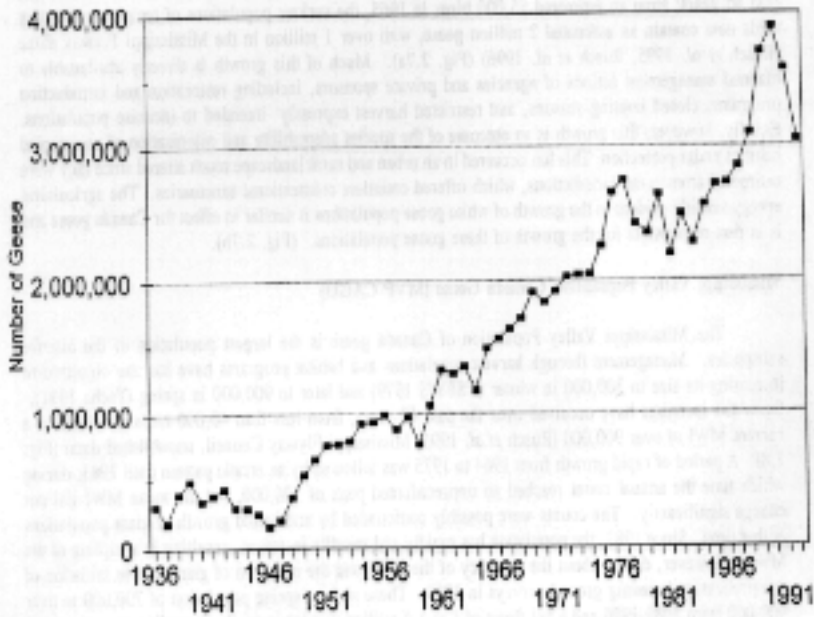


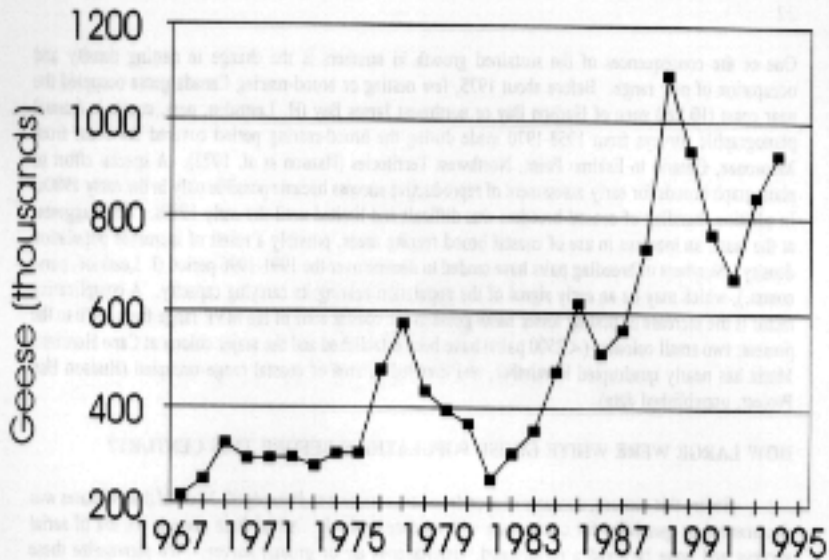


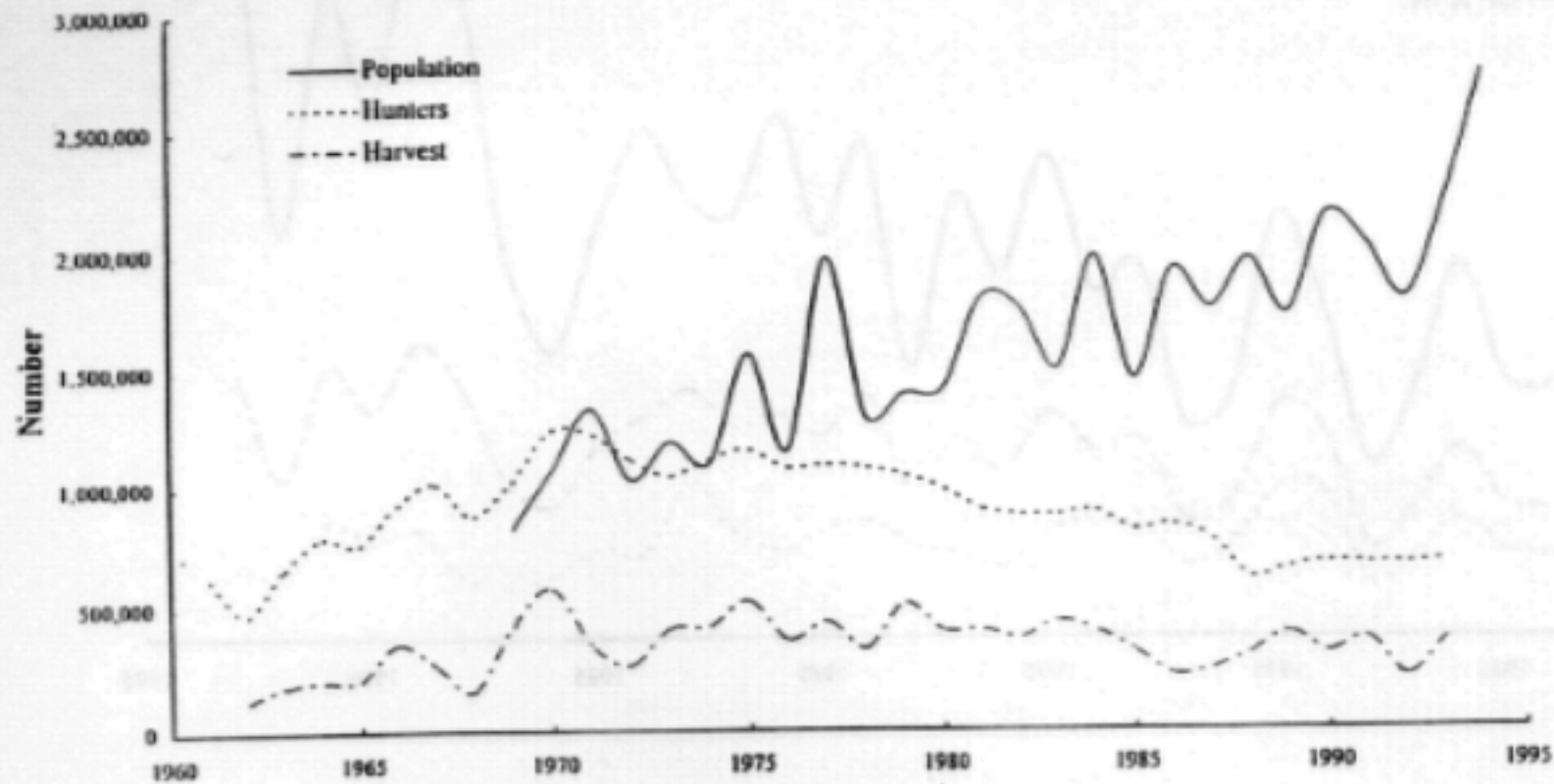


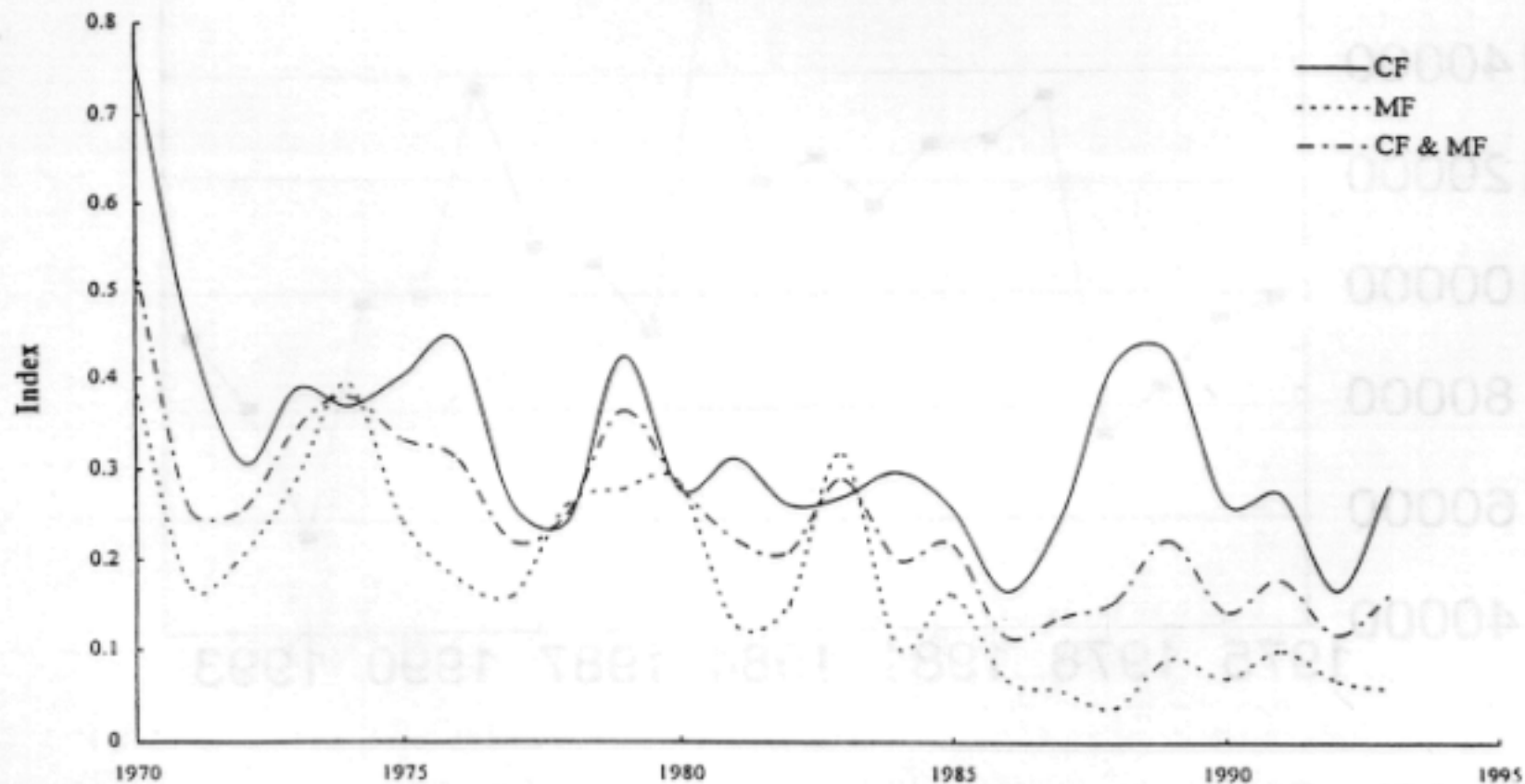
Geese (thousands)

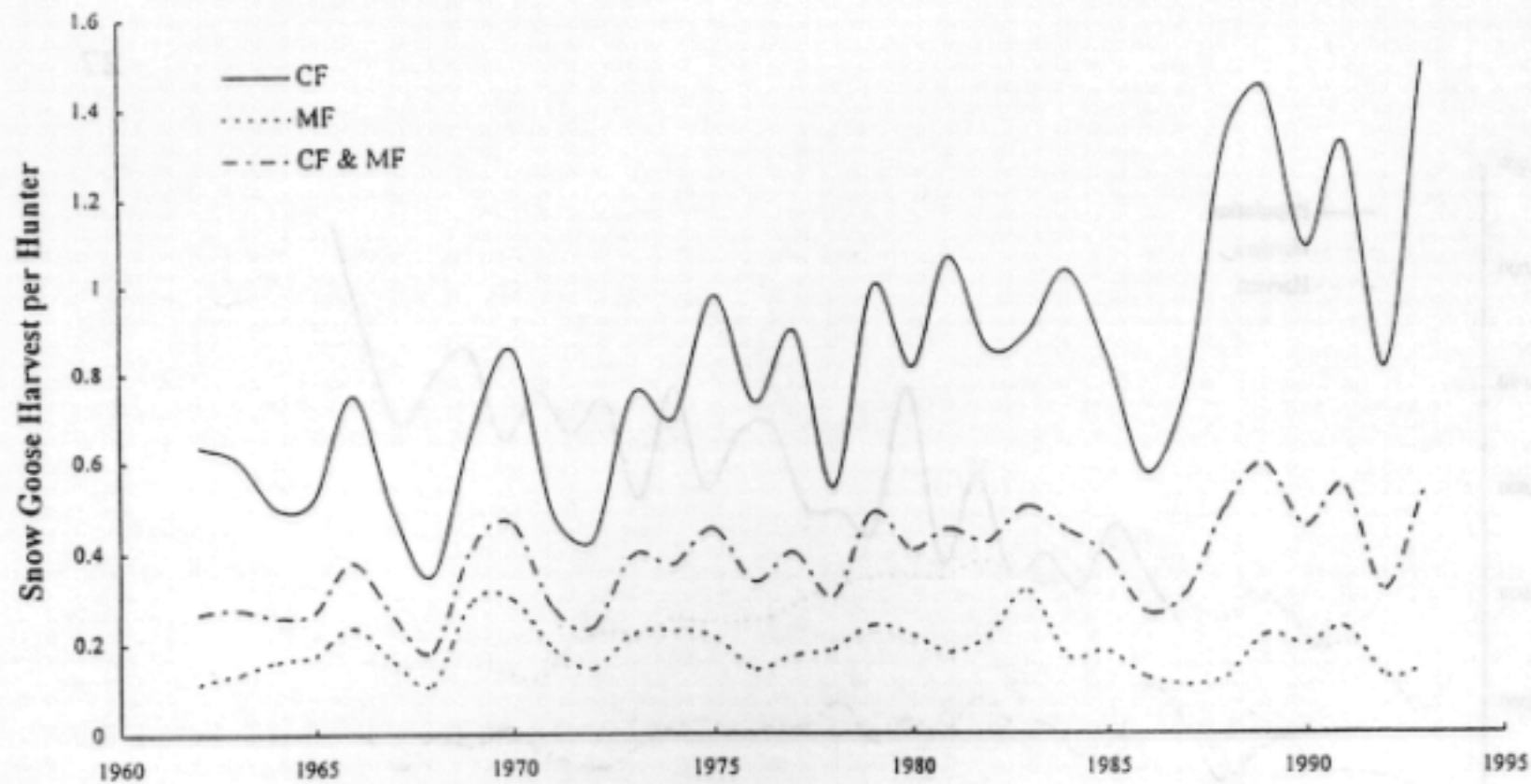


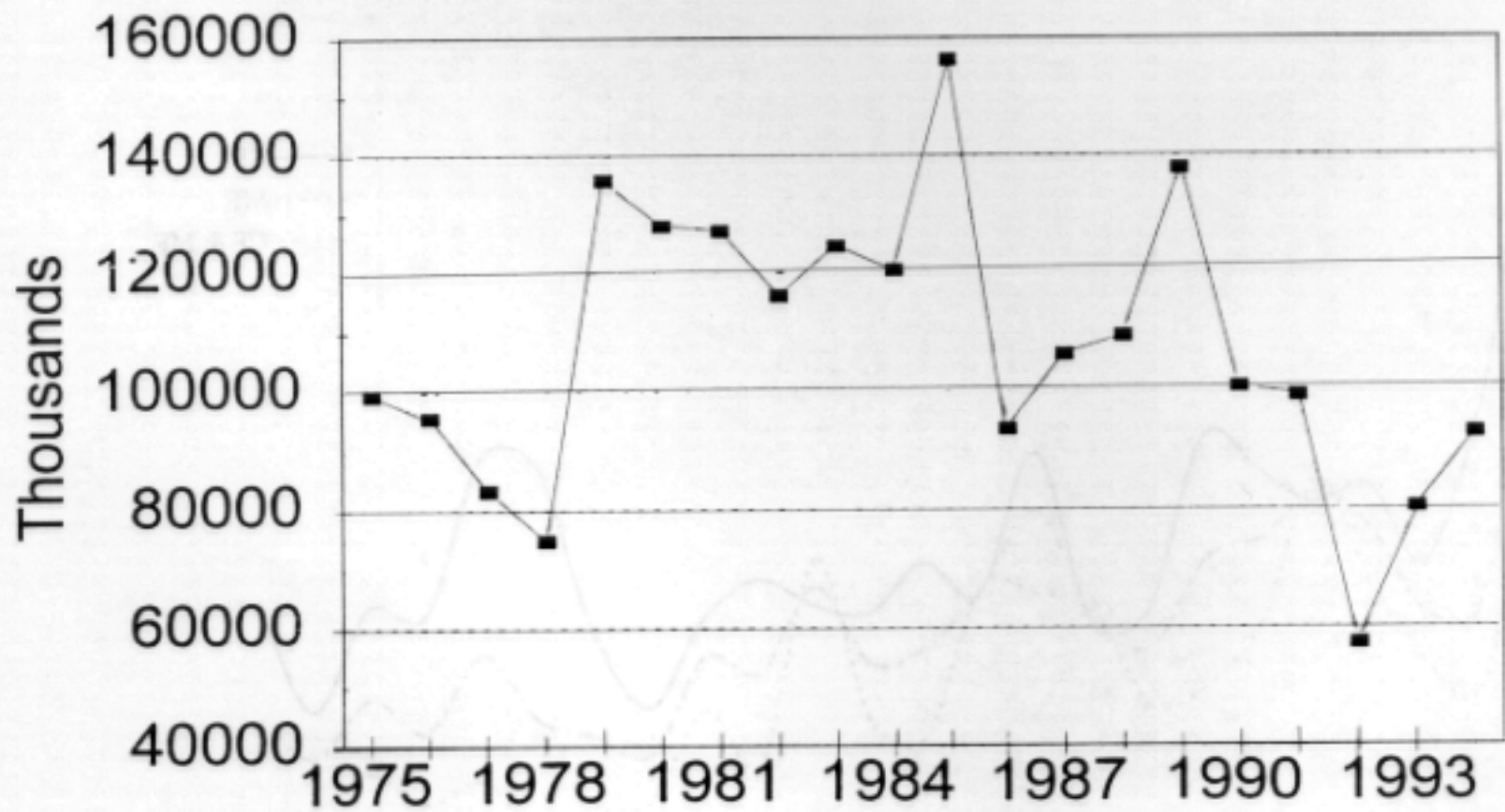












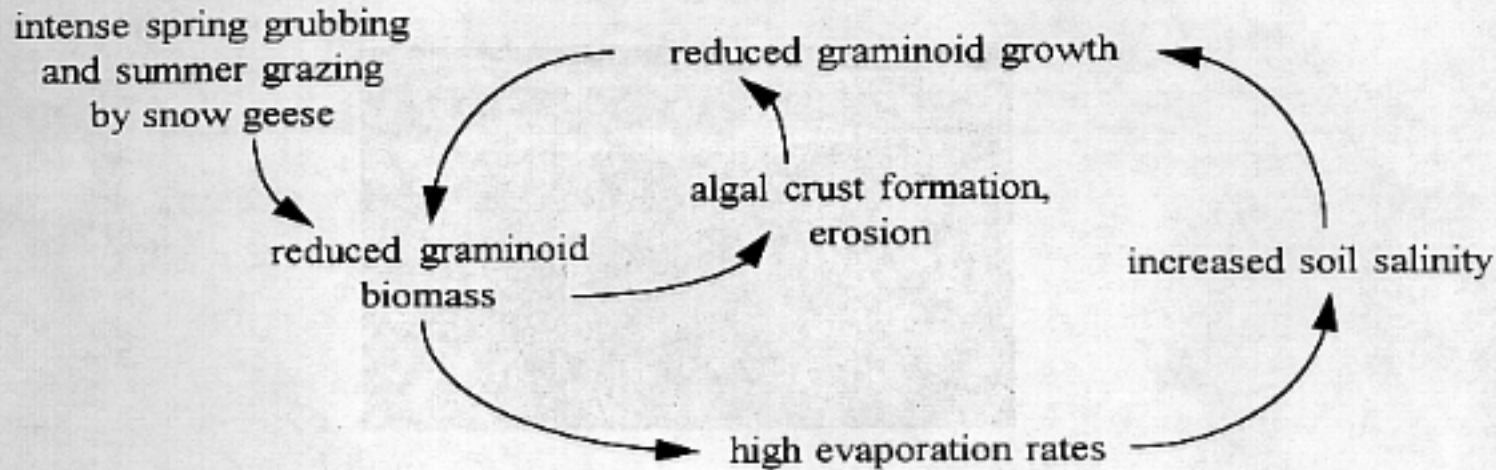


Figure 2.14. Positive feedback in salt marsh desertification.

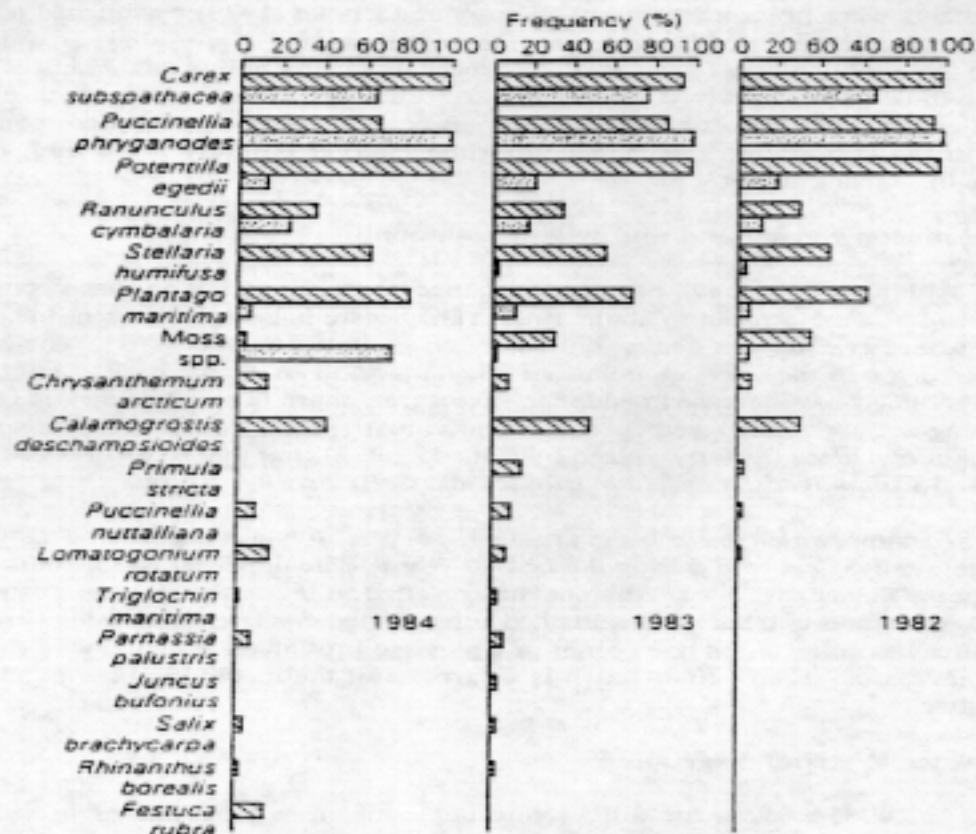
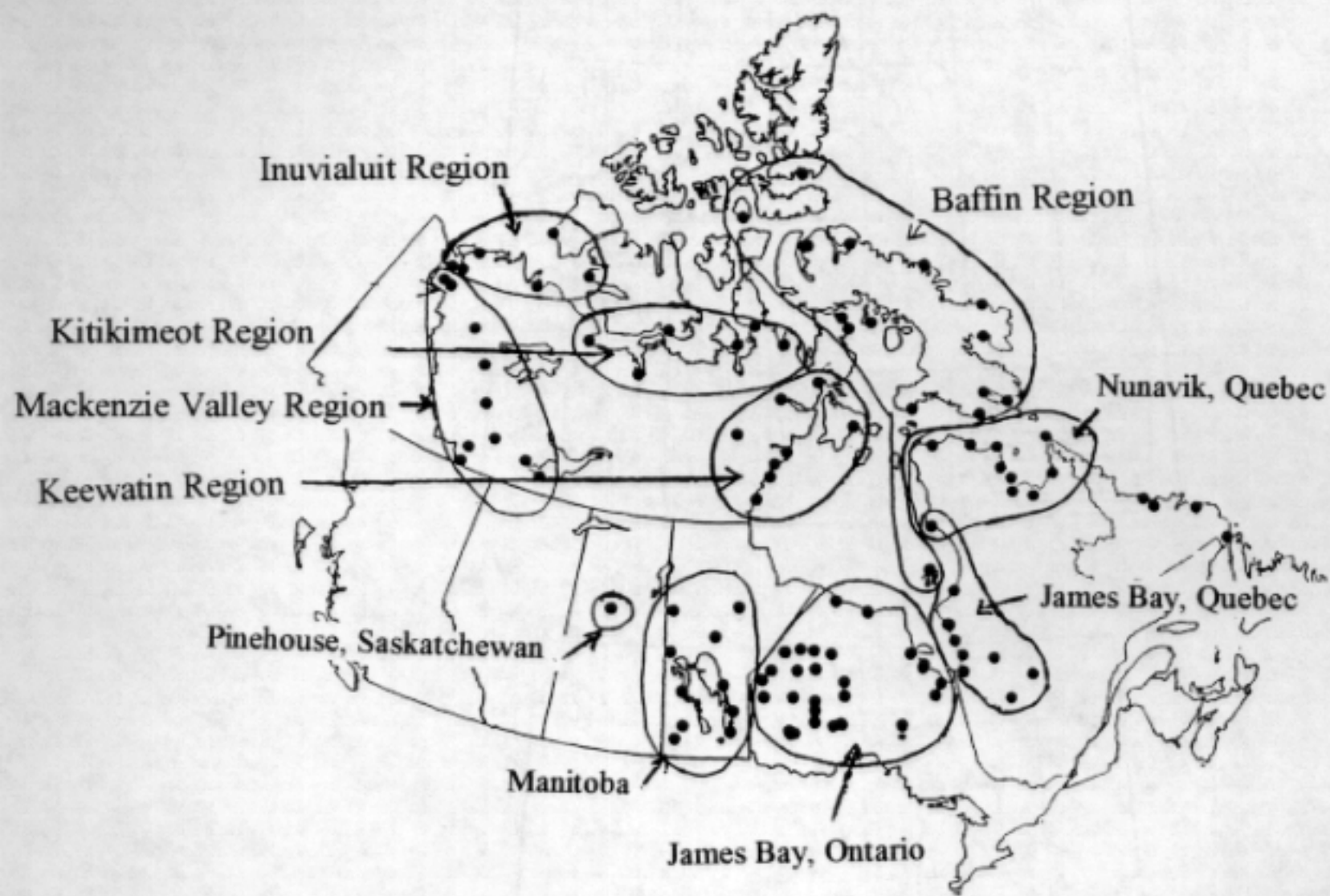
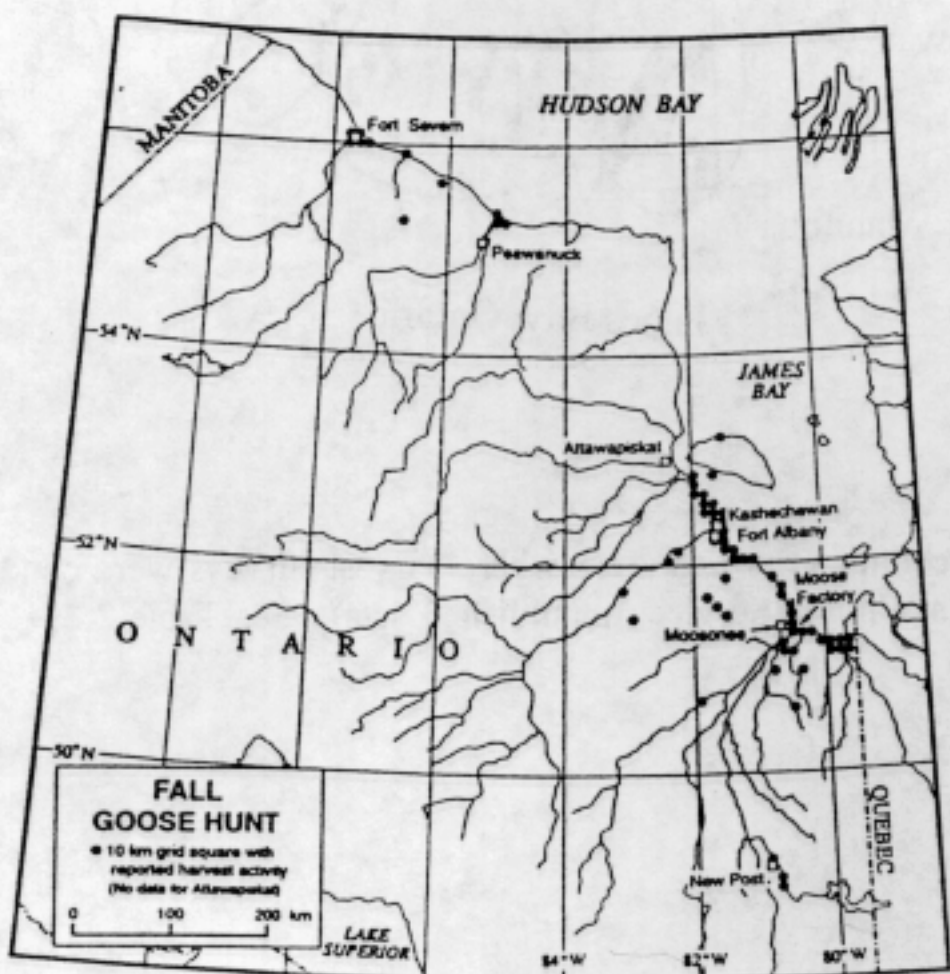
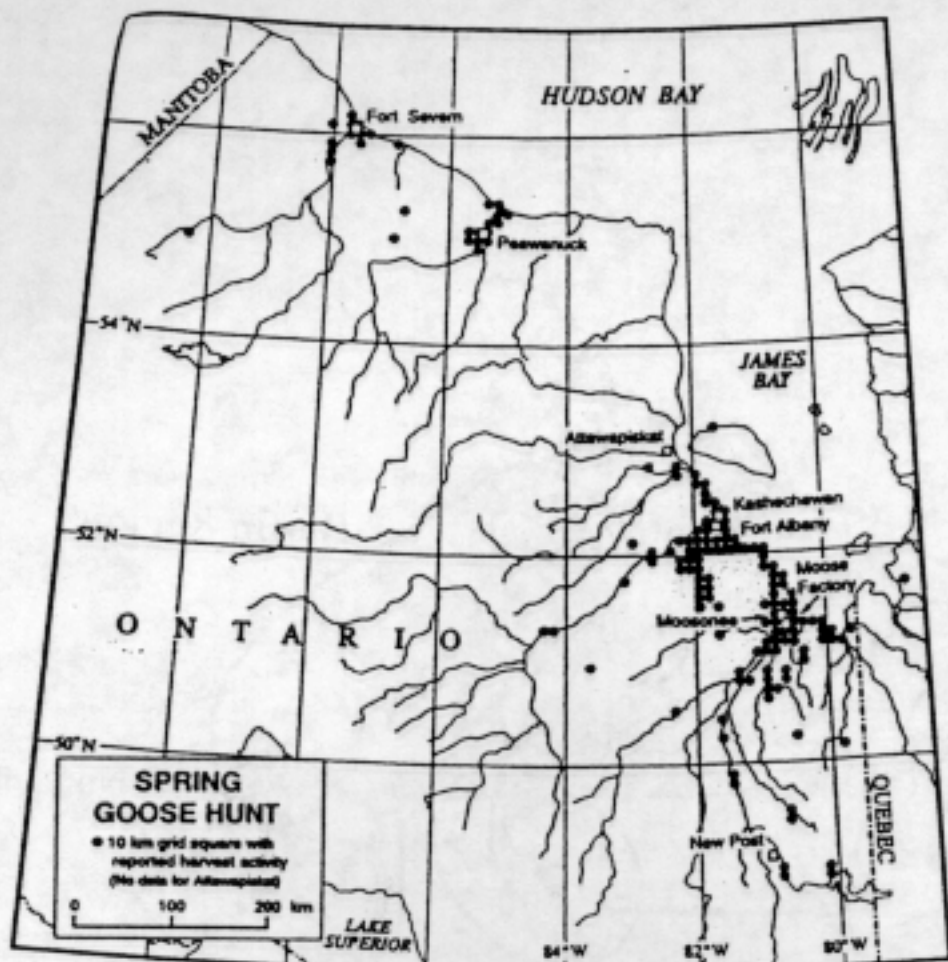
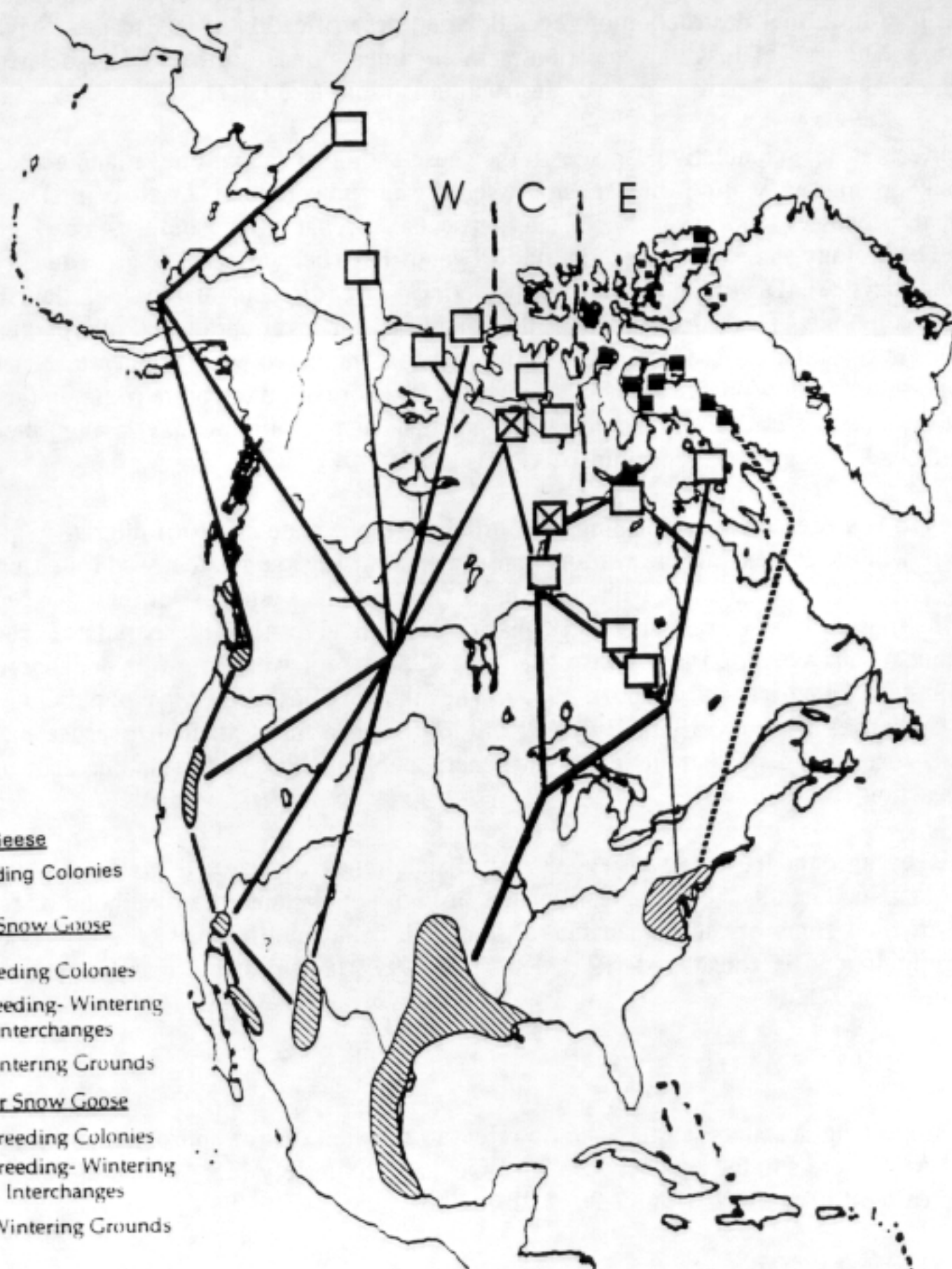


Figure 2.19. Percentage frequencies of species in a salt marsh at La Pérouse Bay, Manitoba in 1982-1984; ▨, in an enclosure (5 m x 5 m) erected in 1979; and ■, in an adjacent plot where the vegetation is grazed by lesser snow geese. Results based on presence or absence of species in 200 quadrats (5 cm x 5 cm).







Ross' Geese

X Breeding Colonies

Lesser Snow Goose

- Breeding Colonies
- Breeding- Wintering Interchanges
- ▨ Wintering Grounds

Greater Snow Goose

- Breeding Colonies
- Breeding- Wintering Interchanges
- ▨ Wintering Grounds

Table 2.2. Reported estimates of snow goose and Canada goose harvests by aboriginal people in Canada (Data compiled by K. Dickson, CWS, from various harvest surveys, 1971-1992).

REGION	YEARS	SNOW GOOSE HARVEST		CANADA GOOSE HARVEST	
		Mean Annual	Kill / Hunter	Mean Annual	Kill / Hunter
Baffin Region, NWT	1981-84	4,371	3.81	3,540	3.53
Inuvialuit Region, NWT	1986-92	5,611	12.85	592	1.22
Keewatin Region, NWT	1982-85	4,562	4.29	1,354	0.84
Kitikimeot Region, NWT	1989	329	na	2,043	na
Nunavik, Québec	1973-80	8,929	10.26	17,378	24.21
James Bay Québec	1975-79	20,639	9.78	63,136	22.64
James-Hudson Bay, Ontario	1974-76	38,088	60.75	22,700	36.97
	1981-83	50,146	43.92	48,977	23.19
	1990	55,076	37.7	56,536	38.7
Mackenzie Valley, NWT	1971-73	na	2.13	na	na
Manitoba	1984	3,500	2.14	na	na
Pinehouse, Saskatchewan	1983	3	0.05	10	0.15